Adolphus Clay W. Peabody.
Boston City

Vose Astronomy

Say what art
Come tell me

A

SYSTEM

OF

ASTRONOMY,

ON THE PRINCIPLES OF COPERNICUS:

CONTAINING, BESIDES THE USUAL ASTRONOMICAL CALCULATIONS,

A CATALOGUE OF ECLIPSES

VISIBLE IN THE UNITED STATES DURING THE PRESENT CENTURY,

AND THE

TABLES NECESSARY FOR CALCULATING ECLIPSES

AND OTHER COMPUTATIONS ON THE MOTION OF THE CELESTIAL BODIES;

ACCOMPANIED WITH PLATES,

EXPLAINING THE PRINCIPLES OF THE SCIENCE, AND ILLUSTRATING THE ASPECTS OF THE HEAVENS.

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Deus unus potest esse Architectus et Rector tanti operis.—*Cicero.*

Who maketh Arcturus, Orion, and Pleiades.—*Job.*

Concord:

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PREFACE.

The following treatise was undertaken at the suggestion of some friends, and in a persuasion, that a classic of the kind was necessary in our institutions of learning. The larger works on astronomy seemed too unwieldly for common use.—Much of Mr. Ferguson's original work had become obsolete; and it may now be considered as defective, for want of the great improvements of Herschel and his cotemporaries.—Though Dr. Brewster may have supplied the deficiency, he has retained much of the obsolete part, and his work is too expensive for admission into most of our seminaries. The latter objection applies with equal force to Enfield, and some others. Most of the smaller works on astronomy had not been published, or were not known to the author of this, when it was commenced. Though the public are now favored with several compends on astronomy, none of them seem calculated for that class of students, for which this was intended. A system is evidently wanted, which may occupy the middle ground between the larger and smaller works. Such a system it is hoped will here be presented. Though the work was intended to be compressed, nothing considered essential was omitted. The elements for the calculation and projection of eclipses and the requisite tables, seemed indispensible to the student, who would enjoy any degree of satisfaction or arrive at what may be termed knowledge in this sublime study.

The author has endeavoured to avail himself of the most modern improvements in astronomy, to glean in every field that lay open on his way.

The motions and periodical times of the planets were in general calculated from tables considered the most accurate. Should they differ a little from the statements in other books, it is hoped and believed, they will not be found less near the truth.

The tables were calculated for the meridian of Washington City, longitude, as found by Mr. Lambert, 76° 55′ 30. 54″, west from Greenwich. This seemed most useful to the American student, and consonant with the dignity and importance of the nation. For while we cheerfully pay our tribute of gratitude to the " old world" for its vast discoveries in the celestial regions, and to those noble individuals of Europe, who have dared to tread the milky way, "where the soul grows conscious of her birth celestial, and feels herself at home among the stars ;" we remember not only that we are far removed from the eastern world, but are an independent nation. It illy becomes the United States to move as the satellite of any foreign power. The sentiments of every true American must accord with those of the present Chief Magistrate : " While scarcely a year passes over our heads without bringing some new astronomical discovery to light, which we must receive at second hand from Europe, are we not cutting ourselves off from the means of returning light for light, while we have neither observatory nor observer upon our half of the globe, and the earth revolves in perpetual darkness to our unsearching eyes ?"

Calculations made for the City of Washington will answer with little variation for the great body of the United States ; and, where an allowance must occasionally be made for difference of longitude, with equal ease may it be calculated from the meridian of our own capital, as from that of Greenwich or Paris. No pains has been spared to render the tables not only extensive, but complete and accurate. Being carried through the 19th century, they will save much of the time usually spent in bringing the numbers of the old tables to use at the present time. In the problems worked by the terrestrial globe, calculations are made from the Meridian of Greenwich, longitude on the globe being reckoned from that meridian.

For a full understanding of some subjects, it seemed necessary to introduce some trigonometrical calculations, and in a few instances, geometrical demonstrations. For the chapters on eclipses and parallax, the student of leisure and ingenuity would not be satisfied to pass superficially over the principles on which the calculations are founded. Yet there may be many whose time and inclination will not permit them to examine minutely by mathematical computation, and much less by demonstration. The latter class of students may pass over the very small part of the work, which may be thought by a judicious instructor, too abstruse for their investigation. For the convenience of such, the demonstrations in general are printed in a closer type. It is however, highly desirable, that the astronomical student should be well versed in trigonometry. Much of the knowledge of astronomy is founded on this science. Without it the scholar must not only lose much of the satisfaction to be derived from his studies; but can scarcely believe the statements of authors, or that the mathematical results are founded in truth.

Questions in our classical books are become *fashionable.*— The author of this would not deny the merits of every book, in which they are found at large; nor would he detract from the very respectable character of some authors, by whom they have been inserted in our books, or teachers by whom they have been used in our schools. But from his own observation as a teacher, from the natural tendency of inserted questions, and from the information he has received of their use in many of our common schools, he considers their utility as very problematical. Where the questions inserted in the book only, are to be asked, the merest novice may be a teacher; and the answers may be promptly given by the most superficial scholar, with little or no knowledge of the subject.

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Their principal use undoubtedly is in reviews. But even for these it was not thought they would deserve a place in a work of this nature.

In stating the motions of the heavenly bodies, a minute insertion, at least including seconds, was thought necessary, as frequently on these, calculations must be dependant. It is not in all cases, however, requisite, that the student should commit the *minutiæ.* The well informed instructer will easily judge, when the sexigesimals ought to be committed.

In many parts of the work, by carrying the calculations forward, and making them for the western hemisphere, the author was forced to explore new regions, " *terra incognita.*" This was particularly the case in the catalogue of eclipses visible in the century. Though he has taken great pains, he cannot hope his work will be free from error. Communications on this subject will be received with gratitude.

CONTENTS.

Introduction.

Astronomy is the science, which treats of the heavenly bodies. The term is compounded of two Greek words, signifying the law of the stars, or constellations. It is a science of great antiquity, and one of the most useful and sublime, that can employ the contemplation of man. By it are known the figure and magnitude of the earth, and the situation and distance of places the most remote. By it is investigated the cause of inequality in the seasons, the changes of day and night, with all the pleasing variety, afforded by those phenomena. The mariner is dependant on this science for his only sure guide on the trackless ocean. But, above all, Astronomy affords the most enlarged view of the Creator's works. The astronomer seems to open his eyes in a vast and unknown expanse. He beholds the stars, which bespangle and beautify our canopy, magnified into so many suns; surrounded with worlds of unknown extent, constituting systems, multiplied beyond the utmost bound of human imagination, and measured only by the omnipresence of Jehovah; all moving in perfect harmony, in subjection to his omnipotent controul.

DIFFERENT SYSTEMS OF ASTRONOMY.

The learned have formed different hypotheses respecting the position and movement of the great heavenly luminaries.

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Ptolemy, who flourished at Alexandria, or Pelusium, in Egypt, in the reign of Adrian and Antoninus, the Roman emperors, supposed the earth at rest in the centre of the universe, and that the sun, the planets, the comets, and stars, revolved round it once in twenty-four hours. Above the planets this hypothesis placed the firmament of stars and the two crystalline spheres; all included in the *primum mobile*, from which they received their motion.

The different phases of Mercury and Venus, the apparent retrograde motion of the planets, and the whole process of calculating eclipses, show the absurdity of this system.

Tycho Brahe formed a different theory. This nobleman flourished sometime after the true system was published, being born at Knudstorp, in Sweden, 1546;* but, anxious to reconcile the appearances of nature with the literal sense of some passages of Scripture, he adopted some of the greatest absurdities of Ptolemy; while, in other respects, he made his system conformable to the principles of modern astronomy. In this system the earth is supposed at rest, the sun and moon revolving around it, as the centre of their motion, while the other planets revolve round the sun, and are carried with it about the earth.

The phases of Mercury and Venus may be explained by this hypothesis. But the opposition of the superior planets can receive no satisfactory explanation. The absurdity of this system, also, must be obvious in the calculation of eclipses.

The Copernican system is now universally received by astronomers. The revolution of Mercury and Venus round the sun, was discovered by some of the ancient Egyptians. Afterwards, Pythagoras,

* He spent a considerable portion of his time in Denmark—hence considered a Dane.

500 years before the christian era, privately taught his disciples the true solar system. But it was rejected and nearly lost, till revived by Copernicus, a native of Thon, in Polish Prussia, and by him published in 1530. "Here the sun is placed in the centre of the system, about which the planets revolve from west to east. Beyond these, at an immense distance, are placed the fixed stars. The moon revolves round the earth; and the earth turns about its axis. The other secondary planets move round their primaries from west to east, at different distances, and in different periodical times."

It will be seen, that the satellites of Herschel form an exception to the regular motion of secondaries.

Some authors inform us, that Copernicus finished his great work in 1530; but that it did not appear in print, till about the time of his death, which happened on the 22d of May, 1543. He died suddenly by the rupture of a blood vessel, a little after entering his seventy-first year, and a few days after revising the first proof of his work.

Copernicus was favoured in the formation of his system, not only by his own powerful contemplations, but by aids derived from history. "Shocked at the extreme complication of the system of Ptolemy, he tried to find among the ancient philosophers a more simple arrangement of the universe. He found that many of them had supposed Venus and Mercury to move round the Sun: that Nicetas, according to Cicero, made the Earth revolve on its axis, and by this means freed the celestial sphere from that inconceivable velocity which must have been attributed to it to accomplish its diurnal revolution. He learnt from Aristotle and Plutarch that the Pythagoreans had made the Earth and planets move round the Sun, which they placed in the centre of the universe. These luminous ideas struck him ; he applied them to the astronomical observations, which time had multiplied, and had the satisfaction to see them yield, without difficulty, to the theory of the motion of the Earth. The diurnal revolution of the heavens was only an illusion due to the rotation of the Earth, and the precession of the equinoxes is reduced to a slight motion of the terrestrial axis. The circles, imagined by Ptolemy, to explain the alternate direct and retrograde motions of the planets, disappeared. Copernicus only saw in these singular phenomena, the appearances produced by the motion of the Earth round the Sun, with that of the planets : and he determined, hence, the respective dimensions of their orbits, which, till then, were unknown. Finally, every-thing in this system announced that beautiful simplicity in the operations of nature, which delights so much when we are fortunate enough to discover it. Copernicus published it in his work, *On the Celestial Revolutions* ; not to shock received prejudices, he presented it under the form of an hypothesis. " Astronomers," said he, " in his dedication to Paul III., being permitted to imagine circles, to explain the motion of the stars, I thought myself equally entitled to examine if the supposition of the motion of the Earth, would render the theory of these appearances more exact and simple."

Glossary

OF TERMS USED IN THIS AND OTHER ASTRONOMICAL WORKS.

Altitude of a heavenly body above the horizon, is an arch of a vertical circle, intercepted between the centre of the body and the horizon.

Amplitude of a heavenly body, is its distance from the east or west point of the horizon, measured on an arch of that circle, when the body is in it, or referred to it by a vertical.

Antipodes are inhabitants who live under opposite meridians, and in opposite parallels.

Antœci are inhabitants who live under the same meridian, but in opposite parallels, north and south.

Aphelion is the point in a planet's orbit most distant from the sun.

Apogee is the point in the moon's orbit, farthest distant from the earth. It is sometimes applied to the sun, when farthest from the earth.

Apsis is the aphelion or perihelion point. The line, connecting these points, is called the line of the apsides.

Argument is a quantity, by which another quantity required may be found.

Asteriods, a name given by Dr. Herschel to the four small planets, discovered in the present century.

Axis of the sun or a planet is the imaginary line, on which it revolves.

Azimouth of a heavenly body is an arch of the horizon between the meridian and a vertical circle, passing through the body; or it is the distance of the body from the north or south point of the horizon.

Latitude of a heavenly body is its distance north or south from the ecliptic. Degrees of latitude are reckoned on secondaries to the ecliptic, passing through the body.

Latitude on the earth is the distance north or south from the equator, reckoned in degrees and minutes.

Libralian of the moon is a periodical irregularity in her motion, by which exactly the same face is not always presented to the earth.

Limits in a planet's orbit are the two points farthest distant from the nodes.

Longitude on the earth is the distance east or west from some fixed meridian, assumed as first.

Longitude of a heavenly body is the distance on the ecliptic from the first of Aries to the intersection of a secondary passing through the body. This longitude is reckoned eastward, 360°.

Meridian is a great circle of the sphere, drawn from north to south through the poles.

Nebulæ are telescopic stars, having a cloudy appearance.

Nodes are two points, at which a planet's orbit crosses the plane of the ecliptic. That intersection, where a planet passes to the north, is called the ascending node ; the opposite, the descending node.

Nonagesimal is the ninetieth degree of the ecliptic above the horizon.

Notanda, things to be noted, or observed.

Oblate spheroid, a spherical body flatted at the poles.

Obliquity of a circle to the ecliptic, the angular distance between that circle and the ecliptic.

Oblique sphere is a position of the sphere, in which the equator and its parallels cut the horizon in an oblique direction.

Opposition, opposite part of the heavens. Two bodies are said to be in opposition, when they are 180° distant, though they may not be in the same degree of celestial latitude.

Orbit is the figure, which a planet describes in its revolution round the sun, or round its primary.

Parallax is the difference between the true and apparent place of a heavenly body. When the body is in the horizon, it is called horizontal parallax. A planet would appear in its true place, if seen from the centre of the earth. It appears in the apparent, when seen from the earth's surface.

Parallel sphere is a position of the sphere, in which the equator and circles of latitude are parallel to the horizon.

Penumbra is the moon's partial shadow.

Perigee is the point in the moon's orbit nearest the earth. The term is sometimes applied to the sun, when nearest to the earth.

Periœci are inhabitants living in the same parallel, but opposite meridians.

Perihelion is the point in a planet's orbit nearest the sun.

Phases are the different appearances of the moon, Mercury and Venus, as the illuminated side is differently presented.

Phenomenon, appearance.

Phenomena, the plural of phenomenon, appearances, generally, unusual appearances.

Planet, a revolving heavenly body.

Plane of a planet's orbit is the imaginary surface in which it lies; passing through the centre of the planet, it extends indefinitely into the heavens.

Polar circles are two circles drawn round the earth from east to west, parallel to the equator, about 23°, 28′* from the poles; the northern called the *Arctic*, the southern the *Antarctic*, circles.

Poles of a planet's orbit are the extremities of its axis.

Precession of the equinoxes, the retrograde motion of the equinoxes from a fixed point in the heavens.

Primary planets are those which revolve immediately round the sun.

* See Obliquity.

Prime vertical is that vertical circle which crosses the meridian at right angles, cutting the horizon in the cardinal points, east and west.

Projectile force, is that which impels a body in a right line.

Quadrature is the point in the celestial sphere, ninety degrees from the sun.

Quadrant, the fourth part of a circle.

Radius, the extent from the centre of a circle to the circumference.

Refraction, the incurvation of a ray of light from its rectilinear course.

Retrograde motion of a planet, apparent motion from east to west.

Right ascension of a heavenly body is its distance from the first of Aries, reckoned on the equator. If the body be not in the celestial equator, right ascension is reckoned from the point, where the secondary, passing through the body, cuts the equator.

Secant, a line drawn from the centre of a circle through one end of an arch till it meets the tangent.

Secondary planets, or satellites, are those which revolve round some of the primary planets.

Secondary to a great circle, is a great circle crossing it at right angles.

Segment of a circle is any part, greater or less than a semicircle, cut off by a chord.

Sidereal revolution is the time in which a planet moves from a star to the same star again.

Sine is a right line drawn from one end of an arch perpendicular to the radius.

Solstices are two points of the ecliptic, ninety degrees from the equinoxes.

Star, a luminous heavenly body appearing always in the same, or very nearly the same situation ; hence called *fixed star*.

Supplement of an arch, what it wants of 180°.

Synodical revolution is the time intervening between a conjunction of a planet with the sun, and the next conjunction of the same bodies.

Syzygy is the conjunction or opposition of a planet with the sun.

Tangent is a line touching the circumference of a circle, perpendicular to the radius.

Tide, the alternate ebb and flow of the sea.

Transverse is the longest axis of an ellipse.

Tropical revolution is the time intervening between a planet's passing a node, and coming again to the same node.

Tropics are two circles drawn round the earth parallel to the equator, at the distance of about 23° 28′ ; the northern called the tropic of Cancer, the southern the tropic of Capricorn.

Twilight, the partial light observed before sunrise in the morning, and after sunset in the evening.

Vector radius is an imaginary line from a planet in any part of its orbit to the sun.

Versed sine, that part of a diameter or radius which is between the sine of an arch and the circumference ; or it is what the co-sine wants of being equal to radius.

Vertical circles are circles drawn through the zenith and nadir of a place, cutting the horizon at right angles.

Zenith is the point in the heavens directly over the head of the observer. The opposite point is called the *Nadir.* These are the poles of the horizon.

Zodiacal light, a pyramid of light, appearing before the twilight of the morning, and after the twilight of the evening.

Zodiac is a broad circle included between two lines drawn parallel to the ecliptic, at eight degrees distance on each side. This zone includes the orbits of all the planets formerly known.

Zone, a large division of the earth's surface ; literally, a girdle.

CHARACTERS.

☿	Mercury.	Planets.
♀	Venus.	
⊕	Earth.	
♂	Mars.	
⚶	Vesta.	
⚵	Juno.	
⚳	Ceres.	
⚴	Pallas	
♃	Jupiter.	
♄	Saturn.	
♅	Herschel.	

♈	Aries.	Signs.
♉	Taurus.	
♊	Gemini.	
♋	Cancer.	
♌	Leo.	
♍	Virgo.	
♎	Libra.	
♏	Scorpio.	
♐	Sagittarius.	
♑	Capricornus.	
♒	Aquarius.	
♓	Pisces.	

S.	Sign.
°	Degree.
′	Minute.
″	Seconds.
‴	Thirds.
=	Equality.
+	Plus, or Addition.
—	Minus, or Subtraction.

ASTRONOMY.

CHAPTER I.

THE SOLAR SYSTEM.

THE *sun*, his attendant *planets*, and *comets*, constitute the solar system.

SECTION I.—OF THE SUN.

The sun is an object pre-eminent in the solar system. The great source of light and heat, it diffuses its rays to every part of an immense sphere, giving life and motion to innumerable objects. Like its divine Author, while it controuls the greatest, it does not overlook the most minute. According to the Copernican system, it is the centre of all the planetary and cometary motions, all the planets and comets revolving round it in different periods, and at different distances. The sun is considered in the lower focus of the planetary orbits. Strictly, if the focus of Mercury's orbit be considered in the centre of the sun, the focus of Venus' orbit will be in the common centre of gravity between Mercury and the sun; the focus of the earth's orbit, in the common centre of gravity of Mercury, Venus and the sun; and thus of the other planets. The foci of all the orbits, however, except those of Saturn and Herschel, will not be sensibly removed from the centre of the sun. Nor will the foci of Saturn and Herschel be sensibly different from the common centre of gravity between Jupiter and the sun.

The sun, though stationary in respect to surrounding objects, is not destitute of motion. It turns on its axis from west to east, making a revolution in 25d. 15h. 16m., or, according to some, in 25d. 10h. The sun is globular, its diameter being 883,246 miles. The sun's rotation is demonstrated from the revolution of its spots ; and its globular form, from its always appearing a flat, bright circle, whatever side is presented to an observer.

The physical construction of the sun has been an object of much inquiry. Considering the sun a globe of fire, some say, " The sun shines, and his rays collected by concave mirrors, or convex lenses, burn, consume, and melt the most solid bodies, or else convert them into ashes or gas ; wherefore, as the force of the solar rays is diminished by their divergency, in a duplicate ratio of the distances reciprocally taken, it is evident their force and effect are the same, when collected by a burning lens or mirror, as if we were at such distance from the sun, where they were equally dense. The sun's rays, therefore, in the neighbourhood of the sun produce the same effects, as might be expected from the most vehement fire : consequently, the sun is of a fiery substance." There seems force in this reasoning. It would lead us to conclude, that however antiquated the opinion may be, that the sun is a globe of fire, its surface must resemble a vast combustion. But, if heat come from the sun, why is it always cold in the upper regions of the air, though nearer the sun, than the surface of the earth ? and why are the tops of lofty mountains covered with perpetual snow, even under the equator ? It may be answered, that animal heat is generated in the lungs from the oxygen of the atmosphere ; that air is a bad conductor of heat, and of course a good defence against cold, or rather preservative of heat, preventing its escape from the body. The more dense the air, therefore, the warmer in any situation.

The density is considered as decreasing in a geometrical proportion, upwards from the surface of the earth. If the decrease be not always thus proportioned, yet it is certain, that the air becomes very rare in high regions, as fully tested by experiment on the tops of lofty mountains. Hence, the supply of heat from the oxygen of the atmosphere, and the security against cold, or the preservation of heat from the non-conducting power of the air, are greatly diminished. This must affect sensation, and in some degree the thermometer. But this is not the only cause, perhaps not the principal cause, why high regions of the air are cold. Chemists assert, that all bodies, even those to us the most frigid, radiate heat. Hence, on the common surface of the earth, not the great mass of the globe only, but thousands of other bodies, with which we are surrounded, supply us with heat. But the elevated observer on the top of Chimborazo or Himmaleh, is retired, at least in some measure, from the influence of the earth, and of the bodies on its surface. He must exhaust his own treasure of heat, while, except immediately from the sun, he receives next to nothing in return.

The most elevated height, to which human beings can ascend, though very considerable in regard to the height of the atmosphere, is not worthy of consideration, when compared with the distance of the sun. What are four or five miles to ninety-five millions ?

It must, however, be conceded, that besides the powerful attraction of the sun, incompatible with its being a mass of *flame* only, the spots on its surface are conclusive, that, at least in part, it must be composed of other matter.

The hypothesis of Dr. Herschel, respecting the sun, deserves some detail, on account of its ingenuity, and the eminence of its author. Rejecting the names, *spots*, *nuclei*, *penumbræ*, *faculæ*, and *luculi*, he adopts the terms, *openings*, *shallows*, *ridges*, *nodules*, *corrugations*, *indentations*, and *pores*. Openings, he says, are those places, where by the accidental removal of the luminous clouds of the sun, its own solid body may be seen ; and this not being lucid, the openings, through which we see it, may, by a common telescope, be mistaken for mere black spots.

Shallows are extensive and level depressions of the luminous solar clouds, generally surrounding the openings to a considerable distance. As they are less luminous than the rest of the sun, they seem to have some distant, though very imperfect resemblance to penumbræ, which occasioned their being called so formerly.

Ridges are bright elevations of luminous matter, extended in rows of an irregular arrangement.

Nodules are also bright elevations of luminous matter, but confined to a small space. These nodules and ridges, on account of their being brighter than the general surface of the sun, and also differing a little from it in colour, have been called faculæ and luculi.

Corrugations he calls that very particular and remarkable unevenness or asperity, which is peculiar to the luminous solar clouds, and extends all over the surface of the globe of the sun. As the depressed parts of the corrugations are less luminous than the elevated ones, the disk of the sun has a mottled appearance.

Indentations are the depressed or low parts of the corrugations ; they also extend over the whole surface of the luminous solar clouds.

Pores are very small holes or openings about the middle of the indentations.

That the appearances, which have been called spots in the sun, are real openings in the luminous clouds of the solar atmosphere, he evinces by a number of observations. His next series of observations is adduced to prove, that the appearances, which have been called penumbræ, are real depressions or shallows. These are followed by others, alleged to show, that ridges are elevations above the general surface of the luminous clouds of the sun ; that nodules are small but highly elevated luminous places ; that corrugations consist of elevations and depressions ; that the dark places of the corrugations are indentations ; and that the low places of indentations are pores. Hence he infers, that the several phenomena, above enumerated, could not appear, if the shining matter of the sun were a liquid ; since, by the laws of hydrostatics, the openings, shallows, indentations, and pores would instantly be filled up ; and that ridges and nodules could not preserve their elevation for a single moment. Whereas many openings have been known to last for a whole revolution of the sun ; and extensive elevations have remained supported for several days. Much less can it be an elastic fluid of an atmospheric nature ; because this would be still more ready to fill up the low places, and expand itself to a level at the top. It remains, therefore, to allow this shining matter to exist in the manner of empyreal, luminous, or phosphoric clouds, residing in the higher regions of the solar atmosphere.

"It appears highly probable," says Dr. Brewster, "and consistent with other discoveries, that the dark solid nucleus of the sun is the magazine, from which its heat is discharged, while the luminous, or phosphorescent mantle, which that heat freely pervades, is the region whence its light is generated."

These hypotheses, like others respecting the sun, are not free from objection. If the spots are only openings in the solar clouds, why are they stationary, except their rotation, for so long a time ? and why should heat come from the dark body of the sun, rather than from its luminous surface, when that surface has so much the appearance of flame, from which heat is generally diffused on the earth ? But so much uncertainty must ever rest on the matter of the sun, perhaps no theory respecting it, can be free from objection. The improvements of modern chemistry have thrown much light upon heat or caloric. But we are not able to draw satisfactory conclusions respecting its nature. Lord Bacon considered heat "the effect of an intestine motion, or mutual collision of the particles of the body heated, an expansive undulatory motion in the minute parts of the body." Count Rumford's experiments seemed to show, that caloric was "imponderable and capable of being produced ad infinitum from a finite quantity of matter." He concluded, that it must be "an effect arising from some species of corpuscular action amongst the constituent particles of the body." Other chemists consider it "an elastic fluid, sui generis." In following either of these, we meet with obstacles. Perhaps the scientific world must be content, as in attraction, with knowing the operations of caloric, without attempting to investigate its nature.

Any uncertainty respecting caloric, must rest on the physical construction of the sun, the prime agent of heat, in whatever way produced.

The spots on the sun were first discovered by Harriot, an Englishman, or Fabricius, a German, about the year 1610. Some accounts say, they were first seen by Gallileo or Scheiner. Fabricius published an account of his observations on them in 1611. The magnitude and shape of the spots are various. To most of them there is a very dark nucleus, surrounded by an umbra or fainter shade. The boundary between the umbra and nucleus is distinct and well defined; and the part of the umbra nearest the dark nucleus is generally brighter, than the more distant portion.

A spot revolves round the sun, so as to appear at the earth in the same position, in a little more than 27 days. The time is longer than one complete revolution of the sun on its axis, on account of the earth's motion in its orbit. No spots appear near the poles of the sun. They are generally confined to a zone, extending about 35° on each side of the equator; though sometimes they have been seen in the latitude 39° 5′. Not a single spot was seen on the sun from the year 1676 to the year 1684.

The motion of the sun's light is progressive, being a little more than eight minutes coming from the sun to the earth. On this account, the sun, or other heavenly body, does not appear in its true place. Let *S* be the sun, (*Plate V. Fig.* 4,) *A*, *B*, *C*, the equator or a parallel of latitude on the earth. If light were instantaneous, it would be noon at *A*, when the sun is on the meridian, as at *S*. But as light is progressive, a meridian must pass eastward from *A* to *B*, more than two degrees, after the ray starts from the sun, before it arrives at the earth. The sun must appear at *R* when it is over the meridian at *A*. It is therefore always to the west of its apparent place.

Perhaps the student may think it more conformable to the Copernican system to be told, that the light, which on leaving the sun is directed towards him, does not come to him ; but presents the image of that luminary to inhabitants, living more than two degrees to the westward of his meridian.

SECTION II.—OF THE PLANETS.

The word *Planet*, is derived from the Latin *Planeta.*—This is of Greek origin, being derived from PLANAŌ, *I wander, or cause to wander.* The root, or original word, seems to be a Greek primitive, PLANEE, *error or wandering.* Eleven primary planets have been discovered ; Mercury, Venus, the Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Herschel. These all revolve round the sun from west to east in elliptical orbits. (*Plate I. Fig.* 1.)

There are eighteen secondary planets. The earth has one ; Jupiter, four ; Saturn, seven ; and Herschel, six.—The discoveries of the last half century warrant the expectation, that the number of planets, both primary and secondary, may yet be greatly increased.

All the primary planets are subject to two great fundamental laws, discovered by Kepler, and from him called the great laws of Kepler.

1st. If a line be conceived, drawn from the planet to the sun, called a *vector radius*, such line will pass over equal areas, in equal times.

2nd. The squares of the periodical times are as the cubes of their mean distances from the sun.

These laws exist "between the rate of motion in any revolving body, whether primary or secondary, and its distance from the central body, about which it revolves." They must therefore apply to the satellites.

SECTION III.—OF MERCURY.

This planet is nearer the sun, than any other yet discovered. The mean apparent diameter of the sun, as seen from Mercury, is 1° 20′. The distance of Mercury from the sun is to that of our earth, as 4 to 10. Hence the intensity of light and heat, being as the squares of the distances inversely, must be at Mercury as 6¼ to 1 at the earth. (*Plate II.*) The intense heat of Mercury was found by Sir Isaac Newton sufficient to make water boil. This planet, therefore, cannot be peopled by beings constituted like the inhabitants of this earth. No revolution of Mercury on his axis has yet been discovered; unless dependance may be placed on Mr. Schroeter's account of discoveries.

Mercury, according to Dr. Herschel, is equally luminous in every part of his body, having his disk equally well defined, without any dark spots or uneven edge. On the contrary, Mr. Schroeter pretends to have discovered, not dark spots only, but mountains in this planet.*

The brilliancy of light emitted by Mercury; the short period in which discoveries can be made upon his disk, and the position of his body, when seen through the mists of the horizon, have prevented important discoveries in this planet.

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* Full credence seems not to be given to Mr. Schroeter respecting his discoveries in the planets; yet, they have received notice in astronomical works; and some account of them, as they occasionally occur, may be gratifying to the student.

ELEMENTS OF MERCURY.

Character in astronomical works,	☿
Inclination of Mercury's orbit to the ecliptic,	7° 0′ 1″
Diameter,	3180 miles.
Mean diameter as seen from the sun,	16″
Periodical revolution,	87d. 23h. 14′ 33″
Sidereal revolution,	87d. 23h. 15′ 44″
Place of ascending node,	16° 14′ 50″ Taurus.
Place of descending node,	16° 14′ 50″ Scorpio.
Motion of the nodes in longitude for 100 years,	1° 12′ 10″
Retrograde motion of the nodes in 100 years,	11′ 22″
Place of aphelion,	8s 14° 44′ 17″
Motion of the aphelion in longitude for 100 years,	1° 33′ 45″
Diurnal rotation, according to Schroeter,	24h. 5′ 28″
Mean distance from the sun,	37,000,000 miles.
Eccentricity,	7,557,630 miles.

SECTION IV.—OF VENUS.

Next to the sun and moon, Venus is to us the most brilliant of the heavenly bodies. From her inferior to her superior conjunction, she appears west of the sun, and, rising before him, is called Phosphor, Lucifer, or the morning star. From her superior to her inferior conjunction, appearing east of the sun, she sets after him, and is called Hesperus, Vesper, or the evening star. She is east or west of the sun in rotation about 292 days ; though not visible quite so long on account of her nearness to the sun.

The motion of the earth in its orbit, in the same direction with Venus, retards her apparent motion round the sun. Her real revolution is performed in 224d. 16h. 49′ 15″, her apparent, in 585 days nearly. Thus, she appears longer east or west of the sun, than the whole time of a revolution in her orbit.

If there be inhabitants in Mercury, they must, at times, have a much more brilliant view of Venus, than can be enjoyed by us. To them her whole illuminated side is apparent, when at the least distance. But the illuminated side is turned from us, when she is in that part of her orbit, which is nearest to the earth. At her superior conjunction, her bright side is turned nearly or quite towards us ; but she is then, either hidden behind the sun, or so near him, as to be invisible to us. When she first appears in the part of her orbit, opposite to the earth, her disk, though nearly round, is rendered small by distance.

The silver light of Venus is extremely pleasant. She is sometimes so brilliant, as to be visible in the day time to the naked eye. In her morning and evening light, shadows have been observed, defined like those of a new moon.

Dr. Herschel observed spots on the surface of Venus, and that she was much brighter round her limb, than at the separation between the enlightened and dark part of her disk.—From this he concluded, that Venus had an atmosphere probably replete with matter, like that of the Earth. He considered the surface of Venus less luminous than her atmosphere. This accounts for the small number of spots apparent on her disk, the surface of the planet being enveloped in her atmosphere. *Plate III. Fig.* 1 and 2, represent the spots in Venus, observed by Bianchini. On the 19th of June, 1780, Dr. Herschel observed the spots, as represented in *Fig.* 3, where *a*, *d*, *c*, is a spot of darkish blue colour, and *c*, *e*, *b*, a brighter spot. They met in an angle at a point *c*, about one third of the diameter of Venus from the cusp *a*. *Fig.* 4 and 5, represent the appearance of Venus with her rugged edge and blunt horn.

" Mr. Schroeter," says Dr. Brewster, " seems to have been very successful in his observations upon Venus ; but the results, which he has obtained, are more different than could have been wished from the observations of Dr. Herschel.—He discovered several mountains in this planet, and found, that like those of the moon, they were always highest in the southern hemisphere, their perpendicular heights being nearly, as the diameters of their respective planets. From the 11th of December, 1789, to the 11th of January, 1790, the southern hemisphere of Venus appeared much blunted with an enlightened mountain, *m*, (*Fig.* 6) in the dark hemisphere, nearly 22 miles high." He states the following result of four mountains measured by him :

	miles.
1st, - - - -	22,05.
2nd, - - - -	18,97.
3rd, - - - -	11,44.
4th, - - - -	10,84.

He supposes, the bluntness and sharpness, alternately observable in the horns of Venus, arise from the shadow of a high mountain.

From the changes, which take place in her dark spots, and, as Schroeter inferred, from the illumination of her cusps, when she is near her inferior conjunction, the atmosphere of Venus is considered very dense.

Venus has been considered about 220 miles less in diameter, than the earth ; but from the measurements of Dr. Herschel, it appears, that her apparent mean diameter, reduced to the distance of the earth, is 18″,79, when that of the earth is 17″,2. " This result," says Dr. Brewster, " is rather surprising, but the observations have the appearance of accuracy."

ELEMENTS OF VENUS.

Character,	♀
Inclination of her orbit to the ecliptic,	2° 23′ 32″
Diameter,	7687* miles.
Mean diameter as seen from the sun,	23′ 3″
Tropical revolution,	224d. 16h. 46′ 15″
Sidereal revolution,	224d. 16h. 49′ 15″
Place of ascending node, Gemini,	15° 5′ 3″
Place of descending node, Sagittarius,	15° 5′ 3″
Motion of the nodes in longitude for 100 years,	51′ 40″
Retrograde motion of the nodes in 100 years,	31′ 52″
Place of aphelion,	10s 3° 56′ 27″

* According to Dr. Herschel, 8643.

Motion of the aphelion in longitude for 100 years, - -	1° 21′ 0″
Diurnal rotation, - - - - - -	23h. 20′ 59″
Mean distance from the sun, - - - -	68,000,000 miles.
Eccentricity, - - - - - -	473,100 miles.

SECTION V.—OF MERCURY AND VENUS.

Mercury and Venus are called *inferior* planets, because their orbits are within that of the earth, or they are nearer the sun than the earth.* These planets are often in conjunction with the sun; never in opposition.

The *inferior* conjunction of Mercury or Venus is, when, in the part of its orbit next to the earth, it falls into the same secondary with the sun; the *superior*, when, on the opposite side of its orbit, it falls into the same longitude with the sun. In the former case, the planet comes between the earth and the sun, or as near a line with them, as the obliquity of its orbit will admit; in the latter, it passes beyond the sun.

When an inferior planet is at its greatest elongation, a line drawn from the earth through the planet, is a tangent to the planet's orbit. Mercury's greatest elongation is 28° 20′; Venus' 47° 48′. The position of these planets at the greatest elongation may be seen in *Fig.* 1, of *Plate V*, where they appear stationary.

The orbits of these and of the other planets, as before stated, are elliptical, having the sun in the lower focus. Mercury and Venus, in moving from the superior conjunction to the inferior, set after the sun; from the inferior to the superior, they rise before him.

The greatest elongation of these planets on one side of the sun may not be equal to that on the other. This is manifest, their orbits being elliptical.

* Some have objected to the terms *superior* and *inferior*, as applied to the planets. But these terms are sanctioned by long usage; and occur in the works of the first European astronomers.

The apparent velocity of the inferior planets is greatest at the conjunctions. Their geocentric motion from the greatest elongation on one side, to the greatest elongation on the other, through the superior conjunction, is direct; through the inferior conjunction this motion is retrograde. At their greatest elongation they appear stationary. The eye of the spectator being in the tangent line, and a small part of the orbit nearly coinciding with that line, the motion of the planet must be either towards the spectator or from him, and of course must be imperceptible.

Let *S* be the sun, *E* the earth, *M* Mercury, and *V* Venus. (*Plate V. Fig.* 1.) When the earth is at *i*, Mercury at *b* in his orbit appears stationary at *e*. While Mercury is moving from *b* through his superior conjunction at *c* to *d*, his motion appears direct among the fixed stars from *e* to *f*. At *d* his motion is imperceptible for a little time, when he appears stationary at *f*. But his motion from *d* through his inferior conjunction to *b* appears to be retrograde among the fixed stars from *f* back to *e*, where he again appears stationary.

It must be remembered, that the earth is moving at the same time with Mercury, and around the same focal point. It is the relative velocity of Mercury only, which gives it the appearance of retrograde motion. Venus is subject to the same appearance of direct and retrograde motion.

When Mercury appears at the earth to move from *d* to *b*, the earth appears at Mercury to retrograde among the stars from *h* to *g*, the retrograde appearance being reciprocal. Hence, the superior planets, when in opposition to the sun, appear at the earth in retrograde motion.

As seen from the sun, the motion of all the planets is direct; their stationary or retrograde appearance being caused by the situation and motion of the earth.

Mercury and Venus, while revolving round the sun, appear with all the phases of the moon. (*Plate III. Fig.* 3, 4, 5, 6.)

The sun illuminates one half of each of the planets.* The bright side of Mercury and Venus, at their inferior conjunc tion, is turned from the earth. These planets are then invisible, except at or near the nodes, when they appear as dark spots passing over the sun's disk. At their superior conjunction, they appear nearly full, but never entirely so, as their illuminated sides are never exactly turned towards the earth, except at the nodes, when the planets are hid behind the sun.

SECTION VI.—OF THE EARTH.

The planet, next to Venus in the solar system, is the earth.

The form of the earth is globular. This is evident from its shadow in eclipses of the moon appearing circular ; from the masts of a ship at sea being often seen, when the hull is hid behind the convexity of the water ; from clouds rising above the horizon, and again sinking below it. But its globular figure is placed beyond doubt, by its having been circumnavigated many times.

The true figure of the earth is an *oblate spheroid.* The equatorial diameter is reckoned by Dr. Rees at 7977, and the polar at 7940 English miles. These, however, he assumes, not as being perfectly correct, but " an approximation to the best estimation." Dr. Bowditch makes the diameter 7964. This is taken as the mean diameter in the following work.

The earth (*Plate V. Fig.* 5.) is considered as encompassed by six great circles, the *equator*, *meridian*, *ecliptic*, *horizon*, and *two colures*.†

* This has been uniformly said by astronomers. Strictly, the sun illumines a fraction more than half, not only by the refraction of its rays in the atmosphere of the planets, but, being a larger body, it shines over something more than one half of each planet.

† Great circles are those, the planes of which divide the earth into equal hemispheres. The planes of less circles divide the earth into unequal parts.

The *equator* is an imaginary circle drawn round the centre of the earth from east to west.

A *meridian* is a circle passing round the earth from north to south through the poles, and crossing the equator at right angles.* Places lying east and west of each other have different meridians.

The *ecliptic* is a great circle, in which the earth performs its annual revolution ; or in which the sun appears to revolve round the earth. The equator is inclined to the ecliptic in an angle of about 23° 28′. (*See Obliquity.*) The ecliptic is divided into 12 equal parts called signs, each including thirty degrees ; Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces.

The *horizon* is a circle ninety degrees distant from the zenith of any place, the plane of which divides the earth into upper and lower hemispheres. This is called the *rational horizon.* The *sensible horizon* is the circle, which bounds our sight, separating the visible part of the heavens from the invisible.

The *solstitial colure* is a meridian, drawn through the solstitial points, *Cancer* and *Capricorn.* The *equinoctial colure* is also a meridian, drawn through the equinoctial points, *Aries* and *Libra.*

To these six may be added the *zodiac,* a broad circle, included between two lines drawn parallel to the ecliptic, at eight degrees distance on each side. This zone includes the orbits of all the planets, formerly known.

Four less circles are conceived drawn round the earth, parallel to the equator ; *two tropics* and *two polar circles.*

The *tropics* are at about 23° 28′ from the equator ; the northern called the *tropic of Cancer*, the southern, the *tropic of Capricorn.* The polar circles are at about 23° 28′ from the poles ; the northern called the *Arctic*, the southern, the *Antarctic* circle.

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* Half of this is usually called a *meridian.*

Latitude is the distance either north or south from the equator, reckoned in degrees and minutes. The highest latitude is at the poles, 90° distant from the equator.

Parallels of latitude are circles drawn parallel to the equator. The measure of a degree in any parallel of latitude is to that of a degree on the equator, as the co-sine of the latitude is to radius.

Longitude is the distance east or west from some meridian assumed as first. It is reckoned each way; 180° east or west being the greatest longitude. Sometimes navigators reckon longitude one way round the globe. Particular meridians have been taken as first by different nations. The English reckon from the meridian of Greenwich; the French from that of Paris. The meridians of Cadiz, of Teneriffe, of Ferro, and of Philadelphia have all been reckoned as first. The meridian of Washington will probably, hereafter, be assumed as the principal in the United States.* A fixed meridian, from which all the nations might reckon longitude, would be of great convenience. But this, though an object much to be desired, is hardly to be expected.

The inhabitants, on different meridians, have different relative time, each degree making a difference of four minutes, 15°, an hour. (*See Longitude.*)

The surface of the earth is considered as divided into five zones. The *torrid zone* extends from the equator each way to the tropics; the *two temperate zones*, from the tropics to the polar circles; the *two frigid zones*, from the polar circles to the poles.

The ingenious student will perceive the foundation for this division. So far as the torrid zone extends, the sun is vertical, at some time of the year. The temperate zones spread over the whole space from the tropics towards the poles, as far as the regular succession of day and night continues throughout the year. The frigid zones are alternately en-

* See article *Longitude.*

veloped in light and darkness. When the sun is in his greatest declination north, he shines over the north pole of the earth, so that the whole northern frigid zone is illuminated. (*Plate VI. Fig.* 1.) The southern is then entirely dark.—An effect directly contrary is produced, when the sun is in his greatest southern declination.

The earth has three motions; its rotation on its axis; its annual motion round the sun; and the motion of its axis round the poles of the ecliptic.

"The rotation of the earth on its axis, called its diurnal motion, is the most uniform, with which we are acquainted. It is performed in 23h. 56m. 41s. of mean solar time, or one sidereal day." This motion must have been given to the earth at its creation; among the first blessings of an all kind Benefactor, to his creatures in this world. It produces the succession of day and night. This motion is from west to east, causing an apparent motion of the heavenly bodies from east to west.

By this motion the inhabitants on the equator are carried about 1042 miles in an hour. The velocity decreases towards the poles, in a direct proportion as the co-sines of the latitudes. Thus, to find the velocity, per hour, in any latitude, say, as radius is to the co-sine of such latitude; so are 1042 miles, to the distance passed in one hour by any place in that parallel. A place in latitude 43° is carried about 762 miles an hour. St. Petersburgh, in latitude 59° 56′, is carried 522; an inhabitant of Greenland in latitude 80°, only 181 miles an hour.

This motion, when on the side of the earth opposite the sun, unites with the immense velocity occasioned by the earth's motion in its orbit round the sun.

The apparent circles of the heavenly bodies, occasioned by the rotation of the earth on its axis, are very different in different places. The celestial sphere is called *right*, *oblique*, or *parallel*, as the celestial equator is at right angles, oblique angles, or parallel to the horizon. The inhabitants at the equator are in a *right sphere*, all the celestial bodies appearing to rise and set in circles perpendicular to the horizon.—The equinoctial passes through the zenith and nadir, and the poles are in the horizon. Those, who inhabit the intermediate space between the equator and the poles are in an *oblique sphere*. All their circles, formed by the apparent motion of the heavenly bodies, are oblique, but varying in different latitudes, and becoming more inclined to the horizon, as they are farther distant from the equator, till at the poles they either coincide with the horizon, or become parallel to that circle.

To a person at a distance from the equator, the stars, the same number of degrees from the elevated pole, do not set, but appear to revolve round, in circles, greater, as they are farther distant from the pole.

Could a spectator be transported to either pole, he would be in a parallel sphere, and would have a prospect singular and sublime. All the visible stars, the polar star excepted,* would appear to revolve in circles parallel to the horizon.—The sun and planets would appear to rise very gradually in spiral circles, more and more elevated, till they arrive at their greatest altitude, which to the sun would be about 23° 28′. Some of the planets would rise higher; particularly the asteroids. The moon would, at times, rise higher than any of the primaries, formerly known, except Mercury; being sometimes 28° 36′ 41″, above the visible horizon.

The earth's annual motion round the sun forms its orbit. This is an ellipse, with the sun in its lower focus. The apparent motion of the sun in the ecliptic is caused by this revolution of the earth in its orbit, the sun and earth always appearing in opposite signs.

The irregularity of the earth's motion in its orbit, was first discovered by Hipparchus, about 140 years before the Christian era. It long perplexed succeeding astronomers. Various

* The pole star would appear to describe a very small circle. *See Longitude* in the article Latitude and Longitude.

cycles and epicycles were invented to explain the observed inequality; but the true cause was not understood, till the great discovery of Kepler. He explained it, by assigning to the orbit its true elliptical figure, and establishing the curious law, before named, common to other planetary orbits, that a line, called a vector radius, connecting the revolving body to its principal, always passes over equal areas in equal times.

The axis of the earth in its motion round the sun, though continually changing its place, is nearly parallel to itself.—For if straight lines be drawn, representing the position of the earth's axis in different points of its orbit, these lines would be parallel to each other, except the variation by the precession of the equinoxes. By this and the axis being inclined to the plane of its orbit, (*Plate VI. Fig.* 1,) the annual revolution of the earth produces the different seasons, spring, summer, autumn, and winter; and also causes the climates, and the inequality of day and night, in different parts of the earth.

These may be represented by a common terrestrial globe. While an attendant holds a candle in the middle of a room, or hall, let a person place the globe, taken from the frame, east of the candle, on a level with it; the north pole of the globe so elevated, that the axis may form an angle with the floor of about 23° 28′, but at right angles with a line drawn from the candle to the centre of the sphere. Nearly one half of the globe will be illuminated; though, as the candle is less than the globe, the illuminated part is something less in proportion, than that of the earth, illuminated by the sun. While in this position, let the globe be turned gently round, from west to east. Every part of the surface will pass through a proportion of light and darkness, nearly equal.—This will represent the earth, at the vernal equinox. With the north pole similarly elevated, and the axis parallel to its former position, let the globe be holden directly under the candle, and turned round as before. From the north pole of the globe to the arctic circle, the space representing the northern frigid zone, on the earth, will turn wholly in the light. The southern frigid zone will be entirely dark. Every part north of the equator, as it turns, will enjoy more light than darkness, and proportionably more, as farther distant from the equator, towards the circle of entire light. The reverse will be seen in the southern hemisphere. Here will be a near resemblance of the earth at the summer solstice. A western position of the globe, will represent the autumnal equinox, while that directly over the candle will show the winter solstice. Let the view be enlarged. Instead of the candle and globe, or a figure, let the sun and earth be contemplated, and an idea may be formed of the cause of inequality in days and nights, and of the change of seasons. Considering the great luminaries themselves, their motions, and circles, affords a more correct idea, than the examination of any diagram. Figures, though often useful, generally give a distorted view.

To those, who are not favoured with a globe, a figure may be some assistance. *Plate VI. Fig.* 1, represents the earth at different seasons. Let *E*, *N*, *Q*, *S*, be the earth, *N* the north and *S* the south pole. It must be apparent, from the representation, that in spring and autumn the tropics, the polar circles, and all the parallels, are one half in the light, and that, as any place revolves round the axis of the earth, in its diurnal rotation, it must have a day and night very nearly equal. But in summer, the whole Arctic regions must be in the light, and the Antarctic in darkness, the polar circles just touching the dividing line between light and darkness. The tropic of Cancer and all the parallels north of the equator, to the Arctic circle, must turn more than half in the light; the tropic of Capricorn and all the parallels south of the equator, must turn more than half in the dark. The different length of the lines in the figure must make this apparent. Compare the figure with *Fig.* 5 of *Plate V.* In winter, the scene is reversed, the southern hemisphere taking the greater proportion of light, the northern of darkness.

The difference in the modes of projection, observable in this figure, (*Plate VI. Fig.* 1.) was for convenience of representing the earth at different seasons. The large ellipse was not intended for the true figure of the earth's orbit, but an oblique view of the orbit.

The earth revolves round the sun from a star to the same star again in 365 days, 6h. 9m. 12s.; from an equinox or solstice, to the same again, in 365 days, 5h. 48m. 51.6s.* The former is called the *sidereal* year; the latter, the *tropical*, *equinoctial*, and sometimes, *solstitial* year. This is usually reckoned from the first degree of Aries. From the aphelion of its orbit to the same again, the earth performs its revolution in 365 days, 6h. 14m. 2s. This is called the *anomalistic* year.

The earth is between 7 and 8 days longer in passing the six northern signs, than the six southern. This may be ascertained by comparing the time from the vernal equinox to the autumnal, with that from the autumnal to the vernal. By this inequality, the inhabitants of the northern hemisphere of the earth enjoy a greater share of the sun's influence, than those of the southern.

It is a circumstance not only curious, but tending to confirm the truth of revelation, that about the time of the creation, probably at the very time, the earth being in or about the aphelion, at the time of the vernal equinox, the summers were equal in the two hemispheres. But, by the aphelion moving forward in the signs 1′ 2″† in a year, the northern gained the ascendency. The maximum was about the year 1297 of the christian era. Since which time the difference has been decreasing, and will continue to decrease till about the year 6523, when the summers will again become equal. After that, should the earth continue in its present state,

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* Thus it is computed by La Place, considered a very accurate mathematician. The length of the tropical year is variously stated by authors.

† This is the motion in longitude. If from this 50″,118 be taken, the remainder 11″,882 is the absolute motion of the aphelion in a year. By some this is computed at 11″,75.

the southern inhabitants will have the superiority for more than 10,000 years ; the whole revolution being 20,903 years. It may be observed, however, that this will only bring the aphelion to the first of Libra, which was in conjunction with it at the creation. A complete revolution of the aphelion requires a period of more than 110,000 years.

The earth is in the aphelion of its orbit on the first day of July, in the forepart of the present century, and more than three millions of miles farther from the sun, than on the last day of December, when it is in the perihelion. No doubt the whole earth is warmer at the time of northern winter, than at the time of northern summer. But in winter the rays fall obliquely—in high latitudes, very obliquely. A far less number, therefore, must light on a given area, than when they are more direct, as in summer. (*Plate V. Fig.* 5.) Add to this, that the continuance of the sun above the horizon in winter is short, compared with the long days of summer, and that the heat is proportionally less. Add farther, that three millions of miles, though a great distance, bear a small proportion, compared with 95,000,000 miles.

The seasons in the southern hemisphere are the reverse of those in the northern. Spring and summer in the north are coincident with autumn and winter in the south ; autumn and winter in the north, with spring and summer in the south.

By the transit of Venus over the sun's disk in 1761 and 1769, the mean distance of the earth from the sun was found to be about 95,000,000 miles ; of course the diameter of the orbit must be 190,000,000 miles. This gives a circumference of 596,902,000 miles ; nearly equal to the elliptical orbit. As the earth moves this immense distance in a year, it must travel at a mean rate of 68,091 miles an hour, and 1,634,184 miles every day. At this inconceivable velocity, 140 times greater than that of a cannon ball, are all the inhabitants of the earth carried. Even this is increased on a part of each day by the revolution of the earth on its axis.

That such a velocity should be imperceptible, may shock the credulity of those who are unaccustomed to the contemplation of such objects. But we are to consider, that every object around, even the atmosphere, is carried with us ; so that there is nothing, by which we can compare our motion, except the heavenly bodies. By observations on these, such motion is now rendered past doubt. Its being imperceptible is not wonderful to those who have sailed in a ship or boat on still water. There a person, having obtained the motion of the vessel, feels no inconvenience from its swiftness, and is nearly insensible of movement, but from surrounding objects, till he strikes a shore, or other obstruction. The motion of the earth in its orbit is far more uniform and even, than any movement on the stillest water.

The motion of the earth's axis round the poles of the ecliptic causes the difference between the sidereal and tropical year. For by this motion the equinoxes are annually carried backward 50.118″ of a degree from east to west, contrary to the order of the signs. Thus in every year they meet the sun 20 minutes, 20.4 seconds, the difference between the tropical and sidereal year, before the earth arrives at the point of the heavens, whence it started at the commencement of the year.

From this *precession of the equinoxes*, "and with them all the signs of the ecliptic, it follows, that those stars, which in the infancy of astronomy were in Aries, are now in Taurus ; those of Taurus, in Gemini. Hence likewise it is, that the stars, which rose or set at any particular season of the year, in the times of Hesiod, Eudoxus, Virgil, or Pliny, by no means answer at this time to their descriptions."

The constellations on our celestial globes, placed 30° from the signs, to which they originally belonged, show the motion of the equinoxes for 2154 years. The signs make a complete revolution in 25,858 years. Hence, in something more than 12,000 years, the star, which is called the north pole, will be about 47° from the pole of the earth, and when on the meridian will be in the zenith of some parts of New-England.

How should the contemplation of these celestial motions, and long periods, lead us to improve the short fleeting moments of time assigned to us ; and bring us to admire and adore the wisdom and power of Him, who formed and still governs all with infinite ease ; with whom a " thousand years are as one day !"

SECTION VII.—OF THE MOON.

The earth has one satellite, the moon. This constant attendant is distant from the earth 240,000 miles,* and revolves round it from a point in the ecliptic to the same again, in 27 days, 7 hours, 43 minutes, and 5 seconds ; from a star to the same again, in 27 days, 7 hours, 43 minutes, 12 seconds.† It performs a mean lunation from the sun to the sun again, in 29 days, 12 hours, 44 minutes, 3 seconds. This is called her synodical revolution. The moon always exhibits the same surface to the earth. Hence, it must revolve round its axis in the same time, that it performs a revolution ; or we must suppose, what is very improbable, that the different sides of the moon present the same prospect. Astronomers seem agreed in the former opinion. If it be correct, it is highly probable, that the side of the moon nearest to the earth is composed of matter more dense than the opposite, and that its rotation on its axis is caused by the powerful attraction of the earth.

Let *E*, (*Plate V. Fig.* 2.) be the earth, *A*, *B*, *C*, *D*, the moon in different parts of her orbit ; *a* a mountain on the side of the moon next to the earth. As the moon passes in her orbit from *A* to *B*, 90°, it is manifest,

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* This is taken for the mean distance.

† De la Lande makes the sidereal revolution 27d. 7h. 43′ 11.5259″.

that she must turn on her axis 90°, in order that the same side may be towards the earth ; the mountain will then be at *b*. When the moon is at *C*, having passed half her revolution, the mountain must be at *c*. The moon at *D* presents the mountain at *d*. When the moon comes to *A*, the mountain must have come round to *a* again. So that in one complete revolution, 27 days, 7 hours, 43 minutes, 12 seconds, the moon must have revolved once on its axis, in order that the same side may be towards the earth.

It is surprising, that Dr. Brewster's name must be enumerated among several authors, who state, in substance, " that the moon performs a revolution in 29½ days," and in immediate connexion, " that it turns round on its axis in the same time that it performs a revolution." The latter is in itself true, but not when connected with the former. It is manifest, from a view of the figure, that, when the moon has revolved more than once round, as it does in passing from the sun to the sun again, it must have turned more than once round on its axis, or the same side cannot be presented to the earth.

The diameter of the moon is 2180 miles. But if its apparent diameter be 31′ 8″, as stated by De la Lande, its diameter must be but 2173 miles.

To the lunarians the earth appears like a moon ; but thirteen times as large as the moon does to us. It exhibits all the phases of the moon, but at opposite times, the full being at the change of the moon ; the change at her full. The magnitude of the earth is to that of the moon about as 49 to 1.

" The moon is an opaque globe like the earth, and shines only by reflecting the light of the sun ; therefore, while that half of her which is towards the sun is enlightened, the other half must be dark and invisible. Hence, she disappears when she comes between us and the sun ; because her dark side is then towards us. When she is gone a little way forward, we see a little of her enlightened side, (*Plate IV.*

Fig. 1.) which still increases to our view as she advances forward, until she comes to be opposite to the sun; and then her whole enlightened side is towards the earth, and she appears with a round illuminated orb, which we call the *full moon*, her dark side being then turned away from the earth. From the full she seems to decrease gradually, as she goes through the other half of her course, showing us less and less of her enlightened side every day, till her next change, or conjunction with the sun, and then she disappears as before."—*Ferguson.*

Without doubt, Mr. Ferguson knew, that we never see the moon completely bright and round, her side illuminated by the sun never being turned exactly towards us. She is not directly opposite to the sun, except when in one of her nodes, and then she falls into the earth's shadow.

To illustrate the different views of the moon, let *S* be the sun, (*Plate V. Fig.* 3.) *T* the earth, *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, the moon in different parts of a lunation. The varied appearances at the earth are represented in the external circle at *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*. At *a* the illuminated side is turned from the earth. It is then called "*the dark of the moon.*" At *b* the bright side is seen a little. The part visible is then called "*the new moon.*" At *c* she appears in quadrature, at *d* gibbous, and at *e* full. At *f* she again appears gibbous, at *g* in quadrature, and at *h* as in the "*old of the moon.*" These appearances are called the *phases* of the moon.

It is evident from the moon's phases, that she shines not by her own light. If she did, her globular form would always present her in a full orb, like the sun.

Difference of seasons must be nearly unknown to the lunarians, the axis of the moon being almost perpendicular to the ecliptic.

One half of the moon has an interchange of light and darkness, each continuing about 14¾ days, while the other half enjoys a continued light, the earth being a bright moon to its inhabitants in the absence of the sun. Eclipses of the earth, usually called eclipses of the sun, form but little interruption to its full appearance.

Some astronomers have asserted, with confidence, that the moon has no atmosphere of any visible density. If so, neither winds, nor clouds, nor storms can be known to its inhabitants. Indeed, this circumstance would render it uninhabitable to beings constituted like the inhabitants of this earth. Some have contended, that there is a lunar atmosphere. "It is not yet determined," says Enfield, "whether there is an atmosphere belonging to the moon."

The dark parts of the moon, formerly thought to be seas, are found to be only vast deep cavities, and places not reflecting the sun's light. Many caverns and pits are dark on the side next to the sun, which shows that they are hollow. Besides cavities, large tracts of mountains diversify the prospects of the moon.

The irregularities on the lunar surface are well described by Dr. Brewster, in his supplement to Ferguson's astronomy. "The strata of mountains, and the insulated hills, which mark the disk of this luminary, have evidently no analogy with those in our own globe. (*Plate IV. Fig. 2.*) Her mountainous scenery, however, bears a stronger resemblance to the towering sublimity and the terrific ruggedness of the Alpine regions, than to the tamer inequalities of less elevated countries. Huge masses of rock rise at once from the plains, and raise their peaked summits to an immense height in the air, while projecting crags spring from their rugged flanks, and threatening the valleys below, seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent mass; and when we examine the rents and ravines, which accompany the overhanging cliffs, we expect every moment, that they are to be torn from their base, and that the process of destructive separation, which we had only contemplated in its effects, is about to be exhibited before us in tremendous reality. The strata of lunar mountains, called the Apennines, which traverse a portion of her disk from northeast to southwest, rise with a precipitous and craggy front from the level of the Mare Imbrium. In some places their perpendicular elevation is above four miles ; and, though they often descend to a much lower level, they present an inaccessible barrier to the northeast, while on the southwest, they sink in gentle declivity to plains.

"The analogy between the surface of the earth and moon fails in a still more remarkable degree, when we examine the circular cavities which appear in every part of her disk. Some of these immense caverns are nearly four miles deep, and forty in diameter. A high regular ridge, marked with lofty peaks and little cavities, generally encircles them ; an insulated mountain frequently rises in their centre, and sometimes they contain smaller cavities of the same nature with themselves. These hollows are most numerous in the southwest part of the moon ; and it is from this cause, that portion of this luminary is more brilliant than any other part of her disk. The mountainous ridges, which encircle the cavities, reflect the greatest quantity of light ; and, from their lying in every possible direction, they appear near the time of full moon like a number of brilliant radiations, issuing from the large spot, called Tycho.

"It is difficult to explain, with any degree of probability, the formation of these immense cavities ; but we cannot help thinking, that our earth would assume the same figure, if all the seas and lakes were removed ; and it is, therefore, probable, that the lunar cavities are intended for the reception of water ; or that they are the beds of lakes and seas, which have formerly existed in that luminary.* The circumstance of there being no water in the moon, is a strong confirmation of this theory. The deep caverns and the broken

* What has become of the water ? Chemists say a body cannot be destroyed.

irregular ground which appear in almost every part of the moon's surface, have induced several astronomers to believe, that these inequalities are of volcanic origin." The hills and valleys of the moon are of great use to us, by reflecting the sun's rays in different directions.

If the surface of the moon were smooth and polished like a mirror, or covered with water, she would never reflect the rays of the sun in the copious manner they are now diffused; but in some positions would show us his image not larger than a point, with such a lustre as to be hurtful to the organs of vision.

" Dr. Hooke," says Rees' Cyclopædia, " accounting for the reason, why the moon's light affords no perceptible heat, observes, that the quantity of light, which falls on the hemisphere of the full moon, is rarified into a sphere 288 times greater in diameter than the moon, before it arrives at us; and, consequently, that the moon's light is 104,368 times weaker than that of the sun. It would, therefore, require 104,368 full moons to give a light and heat equal to that of the sun at noon. The light of the moon, condensed by the best mirror, produces no sensible heat upon the thermometer.

" Dr. Smith has endeavoured to show, in his book on optics, that the light of the full moon is but equal to a 900,900 part of the common light of the day, when the sun is hidden by a cloud."

The orbit of the moon is elliptical. The point of the orbit farthest from the earth is called the *apogee*, the point nearest, the *perigee*. The conjunctions and oppositions of the moon with the sun are called by the common name, *syzygies*.

To a spectator at the sun, the moon never appears distant from the earth more than 10′.

Dr. Herschel thought he saw three burning volcanoes in the moon at the same time; two of them nearly extinct, or about to break out; the third showing an actual eruption of fire, or luminous matter.

When the moon is about three or four days old, the part of her disk not enlightened by the sun, is faintly illuminated by light reflected from the earth. The horns of the enlightened part appear to project beyond the old moon, seeming part of a sphere, larger than the unenlightened part. This may be an optical illusion. Any object bright appears larger, than the same object faintly illuminated, or dark. When an old building is partly whited, the light part, viewed from a distance, appears to rise above the dark remaining part.

This phenomenon may, however, be caused in part by the different shades on the lunar surface, and the different position of those shades.

The sun or moon near the horizon appears much larger, than when seen on the meridian. This phenomenon is singular, because the disk of either, particularly of the moon, must subtend an angle at the earth, increasing with the apparent height of the luminary. To an inhabitant, who sees the sun or moon at his zenith, the luminary must be about four thousand miles, the semi-diameter of the earth, nearer than to one, who sees it at his horizon. (*Plate VI. Fig.* 3.) Let *E* be the earth, *M* the moon. At *A* the moon at *a* appears in the zenith, at *B* she appears at the same time in or very near the horizon. But an inhabitant at *A* is more than the semi-diameter of the earth nearer to the moon, than an inhabitant at *B*, as must fully appear by an inspection of the figure. She ought, therefore, to subtend a larger angle to an inhabitant at *A*, than to one at *B*. This has been found to be the case, when actual measurement has been applied to her disk. The extraordinary apparent magnitude of the sun or moon at the horizon, must, therefore, be an illusion of our sight.

When we view objects at a distance, they appear smaller or larger, according as we imagine them more or less remote. The medium of vision often assists the imagination. Through a mist or fog, a small bird has been taken for a distant hawk or raven ; and in the dusk of the evening, a small cottage has been mistaken for a distant church. But what principally affects the view of remote objects, is the intervention of other objects. The distance over an extended lake, a wide spread meadow, or plain, seems to be lost. Objects on the opposite side appear small, because the imagination places them at a distance far less than the reality. For the same reason, a ball on the top of a lofty spire, appears at the ground far less than its true dimensions. But intervening objects seem, in some measure, to correct the error of vision respecting those which are more remote.

These considerations may lead us to the true cause of the difference in the apparent magnitude of the sun or moon, when seen on the meridian, or at the horizon. No intervening objects are near to correct our vision of the meridian sun or moon. But at the horizon a distant village or hamlet, or, more frequently, hills or mountains, presenting themselves near the line of our view, seem to remove the heavenly luminaries to a much greater distance. Then, as we truly consider them far off, they appear to be large.

The concavity of the visible heavens seems to vary its form, according to the position of the spectator, as he is elevated on some lofty eminence, or depressed in some enclosed valley. Generally, however, it appears not like a hemisphere, but flatted like part of an oblate spheroid. The diurnal arch of a heavenly body seems a semi-ellipse. At *b* the moon seems at *a* diminished in magnitude, because imagination has placed her near.

Some spots on the moon's disk appear and disappear in rotation ; those on the east and west, on the north and south, being alternately visible and invisible. These phenomena are produced by the moon's *librations*, which are of four kinds.

The daily *libration* arises from a spectator's being carried farther north or south, by the diurnal motion of the earth.

The *libration* of the moon in longitude, is caused by the irregularity of her motion round the earth, and her uniform motion on her axis.

The *libration* of the moon in latitude, arises from the inclination of her orbit to the ecliptic.

The other is a small libration, caused by the earth's action on the spheroidical figure of the moon.

SECTION VIII.—OF MARS.

The planet next to the earth in the solar system, is Mars. The atmosphere of this planet, long considered extraordinary in size and density, causes the remarkable redness of his appearance. When a beam of light passes through a medium, its colour inclines to red, in proportion to the density of the medium and the distance passed. The red, or least refrangible rays will traverse, where the violet, the most refrangible, will be absorbed, or diverted. Hence the beautiful tinge of the morning and evening clouds ; and hence the ruddy appearance of this planet, and of the moon, when eclipsed.

In 1719, Mars being within 2° of his perihelion, and in opposition to the sun, was viewed by Miraldi, through a reflecting telescope, 34 feet long. This planet then appeared superior to Jupiter in brightness and magnitude. (*Plate III. Fig.* 7 and 8.) In *Fig.* 8, a belt, extending half way across his disk, was joined by a shorter belt, forming with it an obtuse angle. By the motion of the angular point thus formed, Miraldi found the period of Mars' diurnal rotation to be 24h. 40m., as before observed by Cassini.

In *Plate III*, *Figs.* 9, 10, 11, 12, 13, 14, 15, 16, and 17, represent different telescopic appearances of Mars. At *a*, in *Fig.* 10, and the following to 17 inclusive, is represented a south polar spot of Mars. This spot in *Fig.* 10, presents a singular phenomenon. Apparently projecting beyond the disk of Mars, it produces a break, which seems the greater on account of the gibbous appearance of the planet, also represented in this figure.

The predominant brightness observed at the polar regions of Mars, leads some to conclude, those regions are covered with perpetual snow. To us Mars appears sometimes gibbous, sometimes nearly full; but never horned.

At Mars the earth and moon must appear like two moons, a larger and a less, changing their situation and phases, but never completely full.

The revolution of Mars round the sun contains about 668 of his own days.

In 1784, Dr. Herschel published an account of a very laborious investigation of all the circumstances relating to the telescopic phenomena of this planet. The result is; the axis of Mars is inclined to the ecliptic 59° 42′. The node of the axis is in 17° 47′ of Pisces. The obliquity of the ecliptic on the globe of Mars is 28° 42′. The point Aries on the ecliptic of Mars answers to our 19° 28′ of Sagittarius. Reduced to the mean distance of the earth from the sun, the equatorial diameter of Mars subtends an angle of 9″ 8‴.—The figure of Mars is an oblate spheroid, the equatorial diameter being to the polar nearly as 16 to 15.

ELEMENTS OF MARS.

Character,	♂
Inclination of Mars' orbit to the ecliptic,	1° 51′ 4″
Mean diameter,	4189 miles.
Mean diameter as seen from the sun,	6″
Tropical revolution,	686d. 22h. 57′ 58″
Sidereal revolution,	686d. 23h. 30′ 35″
Place of ascending node, Taurus,	18° 12′ 24″
Place of descending node, Scorpio,	18° 12′ 24″
Motion of the nodes in longitude for 100 years,	45′ 33′
Retrograde motion of the nodes in 100 years,	37′ 59″
Place of aphelion,	5s 2° 51′ 12″
Motion of the aphelion, in longitude for 100 years,	1° 51′ 40″
Diurnal rotation,	24h. 40′
Mean distance from the sun,	144,000,000 miles.
Eccentricity,	13,474,515 miles.

SECTION IX.—OF VESTA, JUNO, CERES, AND PALLAS.

Beyond Mars are the four lately discovered planets, *Vesta*, *Juno*, *Ceres*, and *Pallas*.

Prior to the discovery of these planets, some astronomers supposed, that there must be a planet between Mars and Jupiter. Irregularities observed in the motions of the old planets seem to have led to this supposition. But what was to them supposition, is to us reality. The discovery of an intervening planet marked the first day of the present century.—After discoveries have shown, that not one planet only, but four occupied the space between Mars and Jupiter.

VESTA.

Vesta was discovered by Dr. Olbers of Bremen, in Lower Saxony, March 29, 1807. This planet appears like a star of the fifth or sixth magnitude, and may be seen in a clear evening by the naked eye. Its light is more intense, pure, and white, than that of the other asteroids. It has no visible disk, and is not surrounded by nebulosity.

The elements of these four small planets may be seen in the general table.

JUNO.

Juno, or Harding, discovered by Mr. Harding of Lilienthal, near Bremen, on the 1st of September, 1804, appears like a star of the eighth magnitude. This planet is of a reddish colour, free from that nebulosity observable in Pallas. Yet it appears by the observations of Mr. Schroeter, that it must have an atmosphere more dense than any of the planets formerly known. This astronomer observed a remarkable variation in the brilliancy of Juno. This he attributes to changes taking place in its atmosphere ; though he thinks, these changes may arise from a diurnal rotation in 27 hours.

Juno is remarkable for the great eccentricity of its orbit, as may be seen in the table of elements.

CERES.

This planet was discovered by Piazzi, astronomer royal at Palermo, January 1, 1801. It appears like a star of the eighth magnitude, being according to some about the extent of the moon; but according to Dr. Herschel, its diameter is thirteen times less than that of the moon.

The planet Ceres is of a colour ruddy, though not very deep. When examined with a magnifying power of about 200, it plainly exhibits a disk, surrounded with an extended and dense atmosphere. By many observations, Mr. Schroeter found this atmosphere 675 miles high, and subject to numerous changes. The visible hemisphere, sometimes overshadowed, at others clear, gives but little opportunity of discovering its diurnal rotation. The atmosphere of Ceres, very dense at the planet and rarer at a distance, like that of the earth, produces very singular variations in its apparent diameter. When the planet is approaching the earth, the disk seems to enlarge much faster than ought to be expected from diminution of distance.

"Mr. Schroeter accounts for the remarkable difference between his measurements and those of Dr. Herschel by maintaining, that the projection-micrometer, used by the English astronomer, was placed at too great a distance from the eye, and that he measured only the middle clear part of the nucleus of the planet."

PALLAS.

Pallas was discovered by Dr. Olbers on the 28th of March, 1802. It is nearly of the same magnitude as Ceres; but of a less ruddy colour. It is surrounded with a nebulosity, similar to that of Ceres, and almost equally extended. It resembles Juno in the eccentricity of its orbit. This planet is distinguished from all the rest of the primary planets, by the great inclination, of its orbit to the ecliptic, being about 35°; nearly five times greater than that of Mercury.

From this inclination and a difference of position in the line of their apsides, while their mean distances are nearly equal, the orbits of these planets intersect each other ; phenomena anomalous in the solar system, except in the newly discovered planets. The orbits of these four, says Dr. Brewster, appear to intersect each other in various places. The points of intersection must be perpetually shifting, according to the changes in the aphelia of the planets.

These small planets, discovered in the present century, are called by Dr. Herschel *asteroids.* Some think the term not very properly applied, as they are really planets. The general name seems not perfectly proper. This however is an object of small moment. But every friend to Christianity must regret that proper names of heathen mythology are applied to the discoveries of Christian countries.

Some have laboured to show, that these four small planets formerly constituted but one body, and that they were separated by some vast explosion. The arguments in support of the hypothesis are not conclusive. They take Juno and Pallas to be the smaller fragments, a supposition not corroborated by observation. A similarity in the inclination of orbits, in the position of the nodes, and in the place of the perihelia are relied on as principal grounds. These deserve consideration. But circumstances like these might take place in original planets. The nodes and perihelia of all the planets, so far as observed, are not stationary, but continually revolving. They may be together now. But this proves nothing ; for we cannot suppose the separating explosion, if ever, was recent. Had the asteroids constituted one planet, since any attention has been paid to astronomy, being sufficiently large for observation by the naked eye, it would have been seen by ancient astronomers, and enumerated among the planets.

The most extravagant idea in the separating hypothesis is the explosion. How vast must this have been, when it could so overcome the mutual attraction of the parts separated, that they should fly asunder forty millions of miles ; or so far as afterwards to revolve in orbits, differing by a mean distance of forty millions of miles! We think the explosive force of Hecla immense, when it can throw lava or cinders one hundred and fifty miles. But how diminutive!—How annihilated in the comparison are all the explosions of Vesuvius and Hecla, of Ætna and Cotopaxi!

Pallas is supposed to have been hurled to the greatest distance from the parent body. But the atmosphere and nebulosity, with which Pallas is surrounded, seem incompatible with the idea of a volcanic origin. For, if we conceive the original planet surrounded with an atmosphere and nebulosity equally dense with that of Pallas, we cannot suppose such atmosphere and nebulosity would have followed that planet in its flight, a flight of inconceivable velocity. Darting through the fluid matter, it would have left it all, or nearly all, behind, with the original planet. The atmospheres of the earth and other planets, it is granted, follow them in their annual revolution. But here the same impulse was, without doubt, originally given to the surrounding fluids, as to the bodies which they accompany.

SECTION X.—OF JUPITER.

Next to the asteroids in the solar system is *Jupiter*, the largest of the planets. The form of Jupiter is an oblate spheroid, his equatorial diameter being to his polar, as 14 to 13. Next to Venus, Jupiter is the most brilliant of the planets. Sometimes he evens surpasses her in brightness. The surface of Jupiter is remarkable, being encompassed with a number of belts or stripes of various shades. These appear different at different times, and even at the same time through telescopes of different powers. The weather being very favourable, they sometimes seem formed of a number of curved lines, like the strokes of an engraving. Sometimes seven or eight belts have been seen at the same time. "So many changes appear in these belts," says Mr. Ferguson, "that they are generally thought to be clouds ; for some of them have been first interrupted and broken, and then have vanished entirely. They have sometimes been observed of different breadths, and afterwards have all become nearly of the same breadth. Large spots have been seen in those belts, and when a belt vanishes, the contiguous spots disappear." Some of these spots, however, seem to make periodical returns. The spot, first observed by Cassini, re-appeared eight times between the years 1665 and 1708.

It again re-appeared in 1713, in the same form and position. May 28, 1780, Dr. Herschel observed the whole disk of Jupiter covered with small curved belts, or rather lines not contiguous, as in *Plate III. Fig.* 18 and 19. Parallel belts, however, are most common, as represented in *Plate III. Fig.* 20 and 21. Hence, some suppose, that the clouds of Jupiter, partaking of the great velocity of his diurnal motion, are formed into strata, parallel to his equator ; that the body of Jupiter reflects less light than the clouds ; and that the belts are the body of the planet, seen through the parallel interstices of the clouds.

ELEMENTS OF JUPITER.

Character, - - - - -	♃
The orbit of Jupiter is inclined to the ecliptic, - -	1° 18′ 51″
Diameter, - - - - - -	89,170 miles.
Mean diameter as seen from the sun, - - -	37′ 7″
Tropical revolution, - - -	11y. 314d. 8h. 41′ 3″
Sidereal revolution, - - -	11y. 314d. 22h. 19′ 0″
Place of ascending node, Cancer, - - -	8° 38′ 59″
Place of descending node, Capricorn, - -	8° 38′ 59″
Motion of the nodes in longitude for 100 years, - -	59′ 30″
Retrograde motion of the nodes in 100 years, - -	24′ 2″
Place of the aphelion, - - -	6s 11° 32′ 0″
Motion of the aphelion in longitude for 100 years, - -	1° 34′ 33″
Diurnal rotation, - - - - - - - -	9h. 55′ 37″
Mean distance from the sun, - - - -	490,000.000 miles.
Eccentricity, - - - -	23,762,635 miles

Jupiter has four satellites, reckoned 1, 2, 3, 4, beginning with the nearest to the primary. The satellites often pass between Jupiter and the sun. They then cause eclipses of the primary, resembling our solar eclipses. The shadow of the secondary is seen passing over the disk of Jupiter in a well defined dark line, forming a chord to the disk.

The satellites are themselves eclipsed by falling into the shadow of Jupiter. They often disappear at some distance from the disk of the planet. The third and fourth sometimes re-appear on the same side of the disk. The shadow of Jupiter is not then on the right line between that planet and the earth, produced beyond the planet, but forms an angle with it, by the relative position of the earth, the sun, and Jupiter.

The eclipses of Jupiter and his satellites, exactly similar to those of the earth and moon, are a full proof, that those distant luminaries are in themselves opaque, and shine only by light derived from the sun.

The eclipses of these satellites are of great utility to the inhabitants of the earth. By these it is found, that light is progressive, which, before their discovery, was thought instantaneous. By them the relative distances between Jupiter, the earth, and the sun, can be ascertained with sufficient accuracy. But their greatest utility is to navigation and geography, by affording one of the best methods, yet known, of ascertaining the longitude of places.

Little, probably, did Galileo think, when he first saw these satellites in 1610, he was making a discovery of so much importance. Here as often is verified the remark of a celebrated traveller, that the Deity every where brings the greatest events from causes apparently the smallest.

Satellites.	Periodical times. d.	h.	m.	sec.	Distances from primary in miles.
1	1	18	28	36	266,000
2	3	13	17	54	423,000
3	7	3	59	36	676,000
4	16	18	5	6	1189,000

SECTION XI.—OF SATURN.

Next beyond Jupiter in the solar system, is *Saturn.* Before the discovery of Herschel, Saturn was considered the most remote of the planets. It shines with a dim feeble light.

The most remarkable phenomenon of Saturn, is a broad ring with which he is encompassed. This ring consists of two concentric rings, detached from each other, and from the body of the planet. It is inclined to the ecliptic in an angle of 31°. It is visible to us, only when the sun and earth are on the same side of its plane. The two parts of the ring lie in the same plane, revolving about an axis perpendicular to that plane, in 10h. 32′ 15″. It casts a deep shadow on that part of the body of Saturn, which is opposite to the sun. Each half of the planet in succession must be involved in this dark shadow, during one half of the planet's annual revolution, almost 15 of our years. For the same term, each in succession must enjoy the light of the double ring, a light more brilliant than that of the planet himself.

In *Plate II*, Saturn and his double ring are represented as in the greatest view, when seen from the earth ; in *Plate III. Fig.* 22, as they would appear to a spectator, placed in a line at right angles to the plane of the ring. In *Plate III. Fig.* 23, a position of Saturn is represented, when the ring is very oblique to the observer.

DIMENSIONS OF THE RING.

	miles.
Inner diameter of the interior ring, - -	146,345
Exterior diameter, - - - - -	184,393
Inner diameter of the external ring, - -	190,248
Exterior diameter, - - - - -	204,883
Breadth of the inner ring, - - - -	20,000*
Breadth of the external ring, - - -	7,200
Breadth of the vacant space, - - -	2,830

* So the books tell us. But if the breadth of the inner ring be equal in different parts, or measured at the same place with the diameters, why should it not be about 19,000 miles, instead of 20,000 ? A small error seems apparent in the stated breadth of the exterior ring.

Dr. Herschel considers the ring of this planet, not any shining matter, or aurora borealis, as some have supposed, but a solid body, of equal density with the planet. He is also of opinion, that the edge of the ring is not flat, but is spherical, or rather spheroidical in its form.

The surface of Saturn is diversified with dark spots and belts. Five belts, nearly parallel to the equator, were observed by Huygens. Several, nearly parallel to the ring, were seen by Dr. Herschel. These belts appear more extensive, in proportion to the body of the planet, than those of Jupiter.

By spots on the surface of Saturn, changing their position, Dr. Herschel ascertained the period of Saturn's diurnal rotation to be 10h. 16′ 0.44″.

The sun's light and heat, to an inhabitant of Saturn, must be about 90 times less than they are to us.

Saturn, viewed with a good telescope, appears of a spheroidical figure. What is remarkable, the flatting at the poles does not seem to begin till a high latitude, 43° 20′. The proportion of his disk, according to Dr. Herschel, is,

Diameter of the greatest curvature, - -	36
Equatorial diameter, - - - - -	35
Polar diameter, - - - - - -	32

ELEMENTS OF SATURN.

Character, ...	♄
Inclination of the orbit to the ecliptic, . .	2° 29′ 34″.8
Diameter, ...	79,042 miles.
Mean diameter as seen from the sun, . . .	18″
Tropical revolution, . . .	29y. 162d. 11h. 30′ 0″
Sidereal revolution, ...	29y. 167d. 0h. 27′
Place of the ascending node, Cancer, . .	22° 9′ 48″
Place of descending node, Capricorn, . . .	22° 9′ 48″
Motion of the nodes in longitude for 100 years, . .	52′ 35″
Retrograde motion of the nodes in 100 years, . . .	30′ 57″
Place of aphelion, ...	8s 29° 31′ 42″
Motion of the aphelion in longitude for 100 years, . .	1° 50′ 7″
Diurnal rotation, ...	10h. 16′
Mean distance from the sun, ...	900,000,000 miles.
Eccentricity, ...	50,958,399 miles

Saturn has seven satellites, which revolve about their primary, and accompany him round the sun.

Satellites.		Periodical times.			Distances from primary in miles.
1		22h.	37′	22″	107,000
2	1d.	8	53	8	135,000
3	1	21	18	27	170,000
4	2	17	41	22	217,000
5	4	12	25	12	303,000
6	15	22	41	13	704,000
7	79	7	48		2050,000

The seventh satellite of this planet, reckoned by some the fifth, surpasses all the others but one in brightness, when at its greatest western elongation, but is very small at other times, entirely disappearing at its greatest eastern elongation. This phenomenon, first observed by Cassini, appears to arise from one part of the satellite being more luminous than the rest. " Dr. Herschel observed this satellite through all its variations of light, and concluded, that, like our moon and the satellites of Jupiter, it turned round its axis at the same time it performed a revolution round the primary planet."—*Dr. Brewster.*

" There is not, perhaps," says Dr. Herschel, " another object in the heavens, that presents us with such a variety of extraordinary phenomena, as the planet Saturn ; a magnificent globe, encompassed by a stupendous double ring ; attended by seven satellites ; ornamented with equatorial belts ; compressed at the poles ; turning upon its axis ; mutually eclipsing its ring and satellites, and eclipsed by them ; the most distant of the rings also turning upon its axis, and the same taking place with the farthest of the satellites ; all the parts of the system of Saturn occasionally reflecting light to each other ; the rings and the moons illuminating the nights of the Saturnian ; the globe and the satellites enlightening the dark parts of the rings ; and the planet and rings throwing back the sun's beams upon the moons, when they are deprived of them, at the time of their conjunctions."

SECTION XII.—OF HERSCHEL.

Herschel, *Uranus*, or *Georgium Sidus*, was discovered by Dr. Herschel, on the 13th of March, 1781. It had, probably, before been seen by astronomers, but was considered a fixed star. Dr. Herschel, when observing the small stars near the feet of Gemini, was struck with the appearance of one larger than the rest, but not so brilliant. Supposing it to be a comet, he observed it with telescopes of different magnifying powers, from 227, with which it was discovered, to 2010. Its apparent magnitude increased in proportion to the magnifying power, contrary to the fixed stars. By measuring its distance from some of the stars, and comparing its situation for several nights, he found, that it moved about 2¼ seconds in an hour. He wrote immediately to the royal society, that it might be observed by other astronomers. It was found and observed by Dr. Maskelyne, who almost immediately declared, he suspected it to be a planet. On the first of April, Dr. H. wrote to the astronomers of Paris an account of his discovery. It was soon observed by all the astronomers of Europe.

So distant is this planet, it can scarcely be discovered by the naked eye. In a serene sky, however, it appears like a star of the sixth magnitude, with a bluish white light, and a brilliancy between Venus and the moon.

ELEMENTS OF HERSCHEL.

Character,	♅*
Inclination of his orbit,	0° 46′ 26″
Mean diameter,	35,112 miles.
Mean diameter as seen from the sun,	4″
Tropical revolution,	83y. 305d. 7h. 21′
Sidereal revolution,	84y. 8d. 9h. 33′
Place of ascending node, Gemini,	12° 57′ 30″
Place of the descending node, Sagittarius,	12° 57′ 30″
Motion of the nodes in longitude for 100 years,	26′ 10″
Retrograde motion of the nodes in 100 years,	57′ 22″
Place of the aphelion,	11s 17° 42′ 49″
Motion of the aphelion in longitude for 100 years,	1° 28′ 0″
Mean distance of the planet from the sun,	1800,000,000 miles.
Eccentricity,	86,263,800 miles.

Six satellites, accompanying Herschel, have been discovered.

"The most remarkable circumstance," says Rees' Cyclopædia, "attending these satellites, is, that they move in a retrograde direction, and revolve in orbits nearly perpendicular to the ecliptic, contrary to the analogy of other satellites; which phenomenon is extremely discouraging, when we attempt to form any hypotheses, relative to the original cause of the planetary motions."

Satellites.	Periodical times.				Distances from primary in miles.
	d.	h.	m.	sec.	
1	5	21	25	20	230,335
2	8	16	57	47	298,838
3	10	23	2	47	348,388
4	13	10	56	29	399,593
5	38	1	48	0	746,240
6	107	16	39	56	1597,708

* "The planet is denoted by this character as the initial of the name, the horizontal bar being crossed by a perpendicular line, forming a kind of cross, the emblem of christianity; denoting, perhaps, that its discovery was made in the Christian era."

GENERAL PLANETARY TABLE.

NAMES.	Mean diameters in English miles.	Mean distance from the sun in round numbers.	Mean diameter as seen from the sun.	Diurnal rotation on axis.			
	Miles.	Miles.	"	d.	h.	m.	s.
The Sun,	883,246			25	15	16	
Mercury,	3,180	37,000,000	16.		24	5	28
Venus,	7,687	68,000,000	23.3		23	20	59
Earth,	7,964	95,000,000	17.3		23	56	4
Moon,	2,180	95,000,000	4.7				
Mars,	4,189	144,000,000	6.		24	40	0
Vesta,	238	225,000,000					
Juno,	1,425	252,000,000					
Ceres,	163 } 1,024 }	263,000,000					
Pallas,	80 } 2,099 }	265,000,000					
Jupiter,	89,170	490,000,000	37.7		9	55	37
Saturn,	79,042	900,000,000	18.		10	16	0
Herschel,	35,112	1800,000,000	4.				

TABLE.—Continued.

NAMES.	Inclination of orbits to ecliptic.			Proportional quantity of matter.	Tropical revolution.				
	°	′	″		y.	d.	h.	m.	s.
The Sun,				333928					
Mercury,	7	0	1	0.1654		87	23	14	33
Venus,	2	23	32	0.8899		224	16	46	15
Earth,				1.		365	5	48	52
Moon,	5	9	3	0 025					
Mars,	1	51	4	0.0875		686	22	57	58
Vesta,	in 1801 7	8	46		3	60	4		
Juno,	13	3	28		4	128			
Ceres,	10	37	34		4	220	12	53	34
Pallas,	34	39	0						
Jupiter,	1	18	51	312 1	11	314	8	41	3
Saturn,	2	29	35	97.76	29	162	11	30	
Herschel,	0	46	26	16.84	83	305	7	21	

TABLE.—Continued.

NAMES.	Sidereal revolution.					Place of aphelion.				Motion in lon. of aphe. in 100y.		
	y.	d.	h.	m.	s.	S.	°	′	″	°	′	″
The Sun,												
Mercury,		87	23	15	44	8	14	44	17	1	33	45
Venus,		224	16	49	15	10	8	56	27	1	21	0
Earth,		365	6	9	12	9	9	48	52	1	43	20
Moon,		27	7	43	12							
Mars,		686	23	30	35	5	2	51	12	1	51	40
Vesta,						in 1809 2	9	42	53			
Juno,						7	29	49	33			
Ceres,						in 1802 4	25	57	15			
Pallas,	4	224	17	32	34	in 1802 10	1	7	0			
Jupiter,	11	314	22	19		6	11	32	0	1	34	33
Saturn,	29	167	0	27		8	29	31	42	1	50	7
Herschel,	84	8	9	33		11	17	42	49	1	28	0

TABLE.—Concluded.

NAMES.	Longitude of ascending node.				Motion of nodes in lon. in 100y.			Retrogr. motion of nodes in 100y.		Eccentricity in English miles.
	S.	°	′	″	°	′	″	′	″	Miles.
The Sun,										
Mercury,	1	16	14	50	1	12	10	11	22	7,557,630
Venus,	2	15	5	3		'51	40	31	52	473,100
Earth,										1,597,325
Moon,										
Mars,	1	18	12	24		45	33	37	59	13,474,515
Vesta,	3	13	1	0						20,974,725
Juno,	5	21	6	37						63,241,920
Ceres,	2	21	6							21,410,830
Pallas,	5	22	28	57						65,269,500
Jupiter,	3	8	38	59		59	30	24	2	23,762,635
Saturn,	3	22	9	48		52	35	30	57	50,958,399
Herschel,	2	12	57	30		26	10	57	22	86,263,800

CHAPTER II.

PHENOMENA OF THE HEAVENS, AS SEEN FROM DIFFERENT PARTS OF THE SOLAR SYSTEM.

SECTION I.—PROSPECT AT THE SUN.

To a spectator at the centre of the system, the planets would appear to move in harmonious order from west to east. He would probably have no means of determining their several distances, but might suppose those farthest distant, which are longest in performing a revolution. Unacquainted with our method of computing time, he would probably take the period of Mercury, with which to compare the periods of the other planets. He would form a conjecture of the magnitude of different bodies, from their apparent diameters compared with the time of their revolutions.

All would not appear to move in the same orbits; but their paths would seem to cross each other at very small angles. If he should make the path of one of the planets a standard, the paths of all the rest would be inclined to it, one half being on one side, and the other half on the other side of the standard. As in equal times they describe equal areas, the spaces passed in a given time, in different parts of the orbits would be unequal, because the orbits are elliptical. The apparent diameters would also vary a little at different times. All the stars would appear at rest, and equally distant.

SECTION II.—PROSPECT AT MERCURY.

To a spectator at Mercury a different view would be presented. Being by the whole of Mercury's orbit nearer to the other planets, at some times than at others, their apparent diameters would to him vary in proportion to their distances. They would all have conjunctions and oppositions. Their motions would appear sometimes direct ; sometimes retrograde. At intervals they would seem stationary. Such a spectator would probably have no idea of a succession of day and night ; unless Mercury revolve on its axis.

SECTION III.—PROSPECT AT THE EARTH.

A still different view is presented at the earth. The inferior planets exhibit conjunctions, but no oppositions ; the superior, conjunctions and oppositions in succession. Here also the planets seem to enlarge or diminish, as they are nearer or more remote ; the superior always appearing largest in the part of their orbits nearest the earth ; the inferior, by the position of their illuminated side assuming the phases of the moon.

The appearance at the earth of looped curves in the motion of the inferior planets round the sun, however ingeniously described and delineated by several astronomers, seems but the product of a fruitful imagination. If the motion of the sun round the earth were real, such would be the appearance at the poles of the ecliptic and other distant stations on lines, perpendicular to the plane of that circle. But at the earth, though the sun seems to go round, such a phenomenon is incompatible with the powers of vision. Motion directly towards an observer or from him, is imperceptible, except by the apparent enlargement or diminution of the moving object. A planet, in such motion, seems stationary. When a planet crosses the line between the earth and sun in its inferior conjunction, or the same line produced in its superior, nothing but retrograde or direct motion appears. That motion of a planet, which is oblique to the earth, may be resolved into two constituent motions. That in a line with the earth and planet cannot be apparent at the former. The other will appear direct or retrograde among the fixed stars.

SECTION IV.—PROSPECT AT JUPITER.

At Jupiter it can scarcely be known, that there are inferior planets; the greatest elongation of the earth not being more than 11° 11′; that of Mars not exceeding 17° 13′.

SECTION V.—PROSPECT AT HERSCHEL.

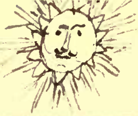
Could an inhabitant of this earth be transported to Herschel, he would almost lose sight of the solar system. To eyes like ours, even assisted by glasses, probably Saturn is the only planet that can be seen at Herschel. The earth can never be more than 3° 2′ from the sun; Mars 4° 38′; Jupiter 15° 48′. But Saturn, having his greatest elongation 30°, may often be seen, exhibiting, exclusive of his ring, the different phases of the moon. Next to the far distant and diminished sun, the satellites of Herschel must be the most luminous bodies in view. For aught we know, however, there may be planets in the system, still farther from the sun, and well known to the inhabitants of the Georgium Sidus. For Omnipotence is not bounded by our limited view.

CHAPTER III.

CAUSES OF THE PLANETARY MOTION.

Projectile force is that, which impels a body in a right line, as the tangent of a circle.

Centrifugal force is that, by which a body, revolving in an orbit, endeavours to recede from the centre.



Centripetal force is that, which attracts a revolving body to the centre.

NOTE.—Centrifugal force differs from projectile, as a part from the whole; being so much of projectile force, in circular motion, as carries the body directly from the centre.

Matter is in itself inactive, and moves only as it is impelled by external force. When an impulse is given to a body, it always moves in a right line, till a different impulse, not in direct opposition or coincidence, turns it out of its course, and gives it a new direction. This new direction will be in a diagonal, formed by the composition of the former motion, and that produced by the last impelling force. Suppose the body *A*, (*Plate VI. Fig.* 2.) at rest, impelled by a momentum, sufficient to carry the body from *A* to *B*, in a given time; it would, uninterrupted, move from *B* to *C*, and from *C* to *D*, equal distances in equal times. But, if at *B* it receive an impulse in the direction *B E*, sufficient to carry it to *E*, in the same time, that the former motion would carry it to *C*, it would move in the diagonal *B F*, and be found at *F* at the same time, that it would have arrived at *C*, unaffected by the latter impulse.—[*See Enfield's Philosophy, Book II, Chap. III, Prop. XIV.*]

Circular or elliptical motion must be produced, not only by an impulse in one direction, but by a continued action, forcing a body from a right line towards a centre.

The planets all move in ellipses, differing, the orbits of the asteroids excepted, but little from circles. From the projectile force, given by the Creator at their formation, and the constant force of gravity, they are kept in their orbits. Let the body *A*, a planet, be projected along the line *A*, *B*, *C*, (*Plate V. Fig.* 6.) meeting with no resistance, it would forever retain the same velocity, and the same direction. For the force, which would carry it from *A* to *B*, in a given time, would, in an equal time, carry it an equal distance from *B* to C, as in *Plate VI. Fig.* 2. But, if at *B* it fall into the attraction of *S*, the sun, which should so balance the projectile force, as to carry it to *E* at the same time, that it would, by its former motion, have arrived at *C*, the planet would now revolve in the circle *B E F*. But should the attraction of *S* be more powerful in proportion to the projectile force, it might bring the planet to *G* instead of *E*, or being still stronger, might carry it nearer the line *B S* in any given proportion. Suppose it carried to *G*, it would revolve in the ellipse, *B G H*. Before it arrives at *G*, and for some distance after, the lines of motion caused by the projectile and centripetal forces form an acute angle. The two powers then conspire to augment each other's motion, and, attraction increasing as the squares of the distances decrease, the motion of the planet would be accelerated all the way in going from *B* to *H*. At *H* it would be nearer the centre of attraction, than at *B*, by twice the eccentricity of its orbit, and, being much more powerfully attracted, would be drawn to *S*, were not the projectile force also increased. This would be now so augmented, that it would carry the planet from *H* to *I*, in the same time, that attraction would bring it to *K*. It would, therefore, be found at *L*, and proceed to *B*, completing the revolution. In going from the perihelion to the aphelion, the planet is as much retarded in its motion by gravity, as it was accelerated in passing from the aphelion to the perihelion. At *B*, the projectile force is so far diminished, that the planet revolves again in the same orbit Thus it appears, " tnat bodies will move in all kinds of ellipses, whether long or short, if the spaces, they move in, be void of resistance. Only those, which move in the longer ellipses, have so much the less projectile force impressed upon them, in the higher parts of their orbits."

Gravity in one part of an orbit operates as projectile force in another. Thus gravity at *B* becomes projectile force at *M*. Though it produces but little by direct operation, yet it is immensely increased by oblique action all the way from *B* to *M*.

A double projectile force will always balance a quadruple power of gravity.

If an angle be taken very small, the arch, the sine, and the tangent very nearly coincide ; the less the angle the nearer the coincidence. In such a case the versed sine may represent the centripetal force, and the tangent, or the arch, to extreme nearness, the projectile.

The larger the orbit is in which a planet moves, the greater must the projectile force be in proportion to the centripetal. In the motion of the earth round the sun, the former is to the latter about as 103 to 1. In the superior planets, and particularly in Hershel, the disproportion is still greater. To us it is inconceivable, that the attraction of the sun can have the least perceptible effect at Herschel, being 3,240,000,000,000,000,000 times less than it is at one mile from the sun. We are, however, to remember, that the planets move in the expansum, where there is no resistance. That a small power would move an immensely large body, balanced in empty space, cannot be doubted. Take away attraction, and we know not but Archimedes might make good his assertion* by the force of his hand. However, that such immense bodies, and so immensely distant from each other, should all move in perfect harmony, may well excite the admiration of man ; but must be infinitely easy to Almighty Power, that at creation " spake and it was done."

CHAPTER IV.

EQUATION OF TIME.

Time as measured by the sun differs from that of a well regulated clock or watch. At four times only in a year do the sun and such clock or watch coincide, viz. on the 14th day of April, the 15th of June, 31st of August, and the 23rd

* " Give me where I may stand, and I will move the earth " This was applied by the celebrated Syracusan to the mechanical force of the lever, but may be true in the case above contemplated.

of December. The days of coincidence on account of longitude are not all the same in the United States as in Europe. The greatest difference happens about the first of November, when the sun is fast of clock 16 min. 14 sec. The inequality is owing to the elliptical figure of the earth's orbit, and the obliquity of the equator to the plane of the ecliptic.

The orbits of the planets being ellipses with the sun in the lower focus, the earth in its annual revolution moves more slowly in the aphelion than in the perihelion of its orbit, as has been shown. The motion on its axis being perfectly uniform, any given meridian will come round to the sun sooner at the aphelion than at the perihelion. Hence the solar day, at the former, will be shorter, and at the latter, longer, than that measured by the clock.

Let *S* be the sun, *T* the earth, *A M P* the earth's orbit, (*Plate VI, Fig.* 4) ; *A* the aphelion, *P* the perihelion, the line *M S* the mean proportional between the semi-axes of the orbit ; the circle *E m* the equator, *m* the point where a meridian cuts the equator. Let *A S a*, *M S n*, *P S p*, be equal areas of the orbit. The arches of these, therefore, by the great law of Kepler, represent the earth's motion in equal times, as a solar day. It is evident, that the point *m*, when the earth is at *a*, at *n*, or at *p*, must pass from *m* to the line *T S*, to complete a solar day. It is also evident, that it must pass farther when the earth is at *p*, than at *a*, the distance at *n* being a mean between the extremes A day therefore, as measured by the sun, will agree with a good time-keeper when the earth is at *M*. At *P* it will be longer, and at *A* shorter than the true day of the clock.

This equation would cause the sun to be faster than the clock while the earth is passing from the aphelion to the perihelion ; the difference increasing to the mean distance, when it would be at a maximum, and decreasing to the perihelion, where the sun and clock would coincide. The sun would be slower than the clock while the earth passed the other half of its orbit, the difference increasing to the mean distance, and decreasing to the aphelion, where again the sun and clock would coincide.

The maximum of this equation is 7′ 43″. The earth being in the aphelion on the first day of July, and the perihelion on the last day of December, in the former part of the present century, the equation is nothing on those days.

The obliquity of the equator to the ecliptic, produces a still greater inequality in the measurement of time. From either equinox to the succeeding solstice, the sun, on account of this obliquity, would be faster than the clock. From the solstices to the equinoxes it would be slower. The vernal equinox happens about the 21st of March, the autumnal, the 23d of September ; the summer solstice, about the 21st of June, the winter, the 22d of December. This equation, when greatest, is about 9′ 54″.

If a line were drawn from the sun to the earth, at the vernal or autumnal equinox, and the earth's axis were perpendicular to such line, forming a tangent to the earth's orbit, the solar and sidereal days, this cause only considered, would be equal, except twice in a year. For any meridian would revolve from the sun to the sun again, in the time of performing a complete revolution. On passing from the equinox, the axis, remaining parallel to itself, would cease to be perpendicular to the vector radius, or line drawn from the sun.— The declination would fast increase to the solstice, where the pole would pass the sun, which would be on the opposite side of the earth till the next solstice. A day at the solstice would be equal to one day and a half of sidereal time.

Let *S* be the sun, (*Plate VI. Fig.* 5.) *A B C D* the earth in different parts of its orbit, *a s* the axis, lying in the plane of the ecliptic, and perpendicular to the vector radius, *e q* the equator, the circle *a e q* the meridian, which is in the plane of the ecliptic, when the earth is at *A* ; *d* the solstice ; *A* the vernal, *E* the autumnal equinox. It is manifest by a view of the figure, that while the earth is passing the quadrant, *A B C*, each revolution will bring the meridian, *a e s* round to the sun. But when it has passed the solstice from *C* to *D*, the meridian must come round from *e* to *q*, performing a revolution and a half, before it can arrive at the sun.

But if the axis were perpendicular to the ecliptic, the solar days would exceed the sidereal, and be equal throughout the year, except the equation arising from the elliptical orbit. In either of these suppositions the sidereal days would be one more than the solar, at any meridian of the earth, in each annual revolution.

Let *S* be the sun, (*Plate VI. Fig.* 6.) *A B C D* the earth, in different parts of its orbit, the circle *e*, *q*, the equator, lying in the plane of the ecliptic, *p*, the visible pole, the extremity of the axis, seen as a point by a spectator at a distance in the direction of the axis; *e p* a meridian next to the sun, seen as a line, by such spectator. It is plain, in this hypothesis, that when the earth has moved from *A* to *B*, the meridian *e p* must move from *m* to the line *S p* before it can come round to the sun, and that in any other part of its orbit, when it has moved an equal distance, as from *C* to *D* the meridian, by turning the same distance from *m* to *S p* will arrive at the sun.

Let the axis be oblique to the ecliptic, as is the case, the difference would not be equable, as in one of the supposed positions, nor at the solstices only, as in the other; but the solar days would be shorter at the equinoxes and longer at the solstices, the less the inclination of the axis to the plane of the ecliptic.

Suppose the axis of the earth inclined to the plane of the ecliptic in an angle of 67°, about its true inclination, and suppose *A B* (*Plate VI. Fig.* 7.) the uniform difference between the sidereal and solar day, were the axis perpendicular to the ecliptic, *B C* an arch of a meridian, then will *A C* less than *A B* be the difference between a sidereal and solar day, when the earth is at the equinox. But with the same inclination, let *A B* (*Plate VI. Fig.* 8.) represent the same uniform difference, when the earth is at the solstice, then the tropics just touch the plane of the ecliptic, and the point of the supposed meridian, vertical to a spectator at the sun, in coming round to the sun, will move for a day nearly in that plane. But as the meridians approach each other, nearer than at the equator, the motion of the earth for the uniform difference, will not bring the meridian round to the sun, but will be short of it, the distance passed being to the distance necessary for arrival at the sun, as *A B* to *A C*.

The intelligent student may easily understand the cause of this equation by inspecting an artificial globe, placed in different positions, so as to represent the earth in the situations before proposed Particular attention to the subject is recommended, as the common mode of explanation by a *fictitious* and *real* sun is Ptolemaick in principle, and gives no just idea of the true cause of this equation.

Table XVIII shews the difference between the sun and a clock keeping exact time, for every day in the year. It is calculated for four years, so as to prevent an error from bissextile. This table, altered from European tables so as to correspond to the time at Washington, will answer without any material error in any part of the United States.

A CONCISE EQUATION TABLE,

Adapted to the second year after leap year. the equations will vary but little from the true equations in any year. The table is convenient for common use to those who wish to keep the difference between the true and apparent time.*

Months.	Days.	Equation. M.	S.	Months.	Days.	Equa. M.	S	Months.	Days.	Equation M.	S.	Months.	Days	Equation M.	S.
Jan.	1	4	21+	April	1	3	46+	Aug.	10	4	54+	Oct.	27	16	0—
	3	5	17		4	2	52		15	4	2	Nov.	8	15	58
	5	6	11		7	1	59		20	2	58		15	15	1
	7	7	2		11	0	53		24	1	57		20	13	55
	10	8	16		14	0	6		27	1	6		23	13	6
	12	9	3		*	——	——		*	——	——		27	11	51
	15	10	8		19	1	5—		31	0	5—		29	11	8
	18	11	7		24	2	6	Sept.	3	1	2	Dec.	2	9	59
	21	11	59		30	3	4		6	2	0		5	8	45
	25	12	58	May	14	4	0		9	3	1		7	7	53
	31	14	0		29	2	59		12	4	3		9	6	59
Feb.	6	14	33	June	5	1	55		15	5	5		11	6	3
	21	13	55		10	0	58		18	6	8		13	5	6
	27	12	56		*	——	——		21	7	11		15	4	8
March	4	11	53		15	0	4+		24	8	13		17	3	9
	8	10	55		20	1	9		27	9	14		19	2	10
	12	9	50		24	2	0		30	10	13		21	1	10
	15	8	59		29	3	1	Oct.	3	11	9		23	0	10
	19	7	48	July	4	3	57		6	12	1		*	——	——
	22	6	53		11	5	3		10	13	5		26	1	19+
	25	5	57		26	6	4		14	14	2		28	2	18
	28	5	1						19	15	0		30	3	17

In the columns marked + the sun is slow of clock; in those marked — it is fast of clock. Therefore when the sign is +, the equation added brings the sun to the clock; when it is —, the equation subtracted brings the sun to the clock.

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* In most concise tables of this kind, minutes only are inserted; but as it is easy in most of our clocks and watches to make allowance for them, it was thought the seconds ought to have place.

CHAPTER V.

PHENOMENA OF THE HARVEST MOON.

The moon's mean motion in her orbit in each solar day of 24 hours, is 13° 10′ 35″. But as the earth moves in the ecliptic at the same time 59′ 8″, the apparent motion of the sun, the moon's motion from the sun is 12° 11′ 27″. Any meridian of the earth in its diurnal rotation, moves this distance in 48′ 38″ of time. But as the moon is also moving, the meridian will not overtake her till 50′ 28″. At the equator, therefore, the moon rises about 50′ 28″ later, each succeeding day, at all seasons of the year. But in high latitudes it is very different. In those latitudes, farmers have long observed the early rising of the autumnal full moon. "In this instance," says Mr. Ferguson, "as in many others, discoverable by astronomy, the wisdom and beneficence of the Deity are conspicuous, who ordered the moon so as to bestow more or less light on all parts of the earth, as their several circumstances and seasons render it more or less serviceable.— About the equator, where there is no variety of seasons, and the weather changes seldom, and at stated times, moon light is not necessary for gathering in the produce of the ground; and there the moon rises about 50 minutes later, every day or night, than on the former. In considerable distances from the equator, where the weather and seasons are more uncertain, the autumnal full moons rise very soon after sunset, for several evenings together. At the polar circles, where the mild season is of short duration, the autumnal full moon rises at sunset, from the first to the third quarter."

These phenomena are caused by the varied positions of the horizon and the moon's orbit. To avoid embarrassment in the explanation, the moon may be considered as moving in the ecliptic, and the obliquity of her orbit, as affecting the harvest moon, afterwards considered.

The plane of the ecliptic forms unequal angles with the horizon of any place on the earth at different parts of the day, and at different seasons of the year.

When the sun enters Libra, about the 23d of September, the earth enters Aries. Then at any place in north latitude, the angle between the horizon and the ecliptic is less about sun setting, than at any other time of day. The full moon, which happens about the autumnal equinox, being in that part of the ecliptic opposite the sun, must rise at this angle, in latitudes below the Arctic circle. There the angle, decreasing with the increase of latitude from the equator, vanishes.

The diurnal motion of the moon in its orbit 13° 10′ 35″ will make but little variation in the time of its rising on each succeeding evening, while it remains in this part of its orbit in all places, when the angle is small. Because the less the angle, the sooner the horizon will overtake the moon.

For illustration, put small patches on the ecliptic of a terrestrial globe, each side of the first degree of Aries at 12° 11′ 27″ from each other, that they may represent the moon's diurnal motion from the sun; rectify the globe for the latitude of the place, suppose 45°, and with the number of patches corresponding to the days of a week, bring the westernmost to the eastern horizon, set the index of the hour circle, at the time of the moon's rising, found by calculation or a diary, on the evening nearest to three and a half days before her arrival at Aries, turn the globe westward, which will represent the rotation of the horizon eastward, in relation to the moon, till the second patch comes to the horizon, and the index will point at the time of the moon's rising on the succeeding evening. Bring the patches in succession to the horizon, and the index will show the time when the moon will rise on each day for a week.

The moon arrives at Aries, at the equinox, when the full happens at that time. But when the equinoctial full falls any number of days before or after the 23d of September, multiply 59′ 8″ by the intervening days, the product reduced to degrees gives the moon's distance from the first of Aries at the full. Compute the time by the moon's diurnal motion. The arrival is later than the full preceding the equinox; earlier, when the equinox precedes the full. These calculations may be much more easily made, by taking a degree for each day, and rejecting odd minutes, both of time and motion. The arrival at the equinox may thus be ascertained with sufficient exactness. The number of patches may be increased or diminished at pleasure, and the rising exhibited for a longer or a shorter time.

If the index be set at 12, when the first patch is brought to the horizon, and the other patches be brought to that circle in succession, the difference of time between the moon's rising on the several nights may be seen on the hour circle.

The harvest moon may be more naturally represented by an artificial globe taken from the frame. Let a candle be placed on a stand to represent the sun, and the globe holden at a little distance west of the candle and on a level with it; but the north pole so elevated, as to form an angle of 23° 28′ with the horizon. A small taper placed under the globe may represent the moon at the first quarter. The taper carried to the west of the globe, may represent her at the full in Aries. Placed over the globe it may show her situation in the last quarter. By turning the globe round, and observing when any place, as Washington, comes into the light of the taper in its different positions, you may see the appearance of the moon rising at that place. If the taper in its western position be moved slowly and circularly up, so as to make $12\frac{1}{5}$° at the globe, while the globe turns once round, and thus continued for several revolutions, nearly the exact appearance of the harvest moon may be represented.

When the moon rises with the least angle, it sets with the greatest; and, when it rises with the greatest, it sets with the least. The time of rising at the full differs the most about the vernal equinox.

The moon passes the same signs in every revolution; but her rising with the least difference, always about the first of Aries, is seldom observed, except in autumn. In winter she enters Aries about the first quarter, and rising in the day time, is scarcely noticed; about the change in spring, and being with the sun, is not seen; in summer, about the last quarter and rising near midnight, is not often observed.

In the quotation from Mr. Ferguson, at the commencement of this article, it was stated, that "at the polar circles, the autumnal full moon rises at sunset from the first to the third quarter." This is not strictly true. At those circles, the moon rises about sunset at the first quarter, and afterwards at the end of each sidereal day nearly to the third.—So that during that time it rises 3′ 56″ earlier on each succeeding day.

When the harvest moon does not happen at the equinox, the fulls immediately before and after exhibit phenomena nearly resembling the equinoctial full; more nearly, as they are nearer the equinox, and as often in Pisces as Aries.

The moon exhibits the same phenomena in south latitudes at opposite times in the year.

There also, wisely ordered by a kind Providence, the full moon in autumn rises with less variation, than at any other season. This happens, when the moon is in Virgo and Libra, the autumnal equinox of south latitude corresponding to the vernal of the north.

The inclination of the moon's orbit to the ecliptic, about 5° 9′, varies in some measure the circumstances of the harvest moon. Her nodes move backward in the ecliptic, performing a revolution in about 18 years 224 days. Half of this time the harvest moon will be most, the other half, least beneficial; most, when her ascending node is in the first degree of Aries, least, when her descending node is in that sign.

The full moon in summer runs much lower in some years than in others. She runs low, when in that part of her orbit, which is south of the ecliptic; lowest, when her latitude south is greatest, or she is 90° from her nodes. The winter full moon runs high, when she is north of the ecliptic; highest, when she is fartherest north, or 90° from her nodes.

Though some of the full moons of summer are lower than others, all are low, and their time above the horizon short.— In winter they are high and long above the horizon, when the dreary and protracted nights make moonlight most beneficial.

At the poles, the full moon is not seen for nearly half the year, being below the horizon. But this is in summer, when, from the continued shining of the sun, moon light would be of no use. In winter, when the light of the moon is most beneficial, at the benighted polar regions, she shines continually, from about the first to the third quarter. Who can contemplate these things, and not admire and adore the wisdom and goodness of Him, who not only "gave the sun for a light by day," but "the moon and stars for a light by night!"

The following table shows in what years the harvest moon is least, and in what most beneficial. *L* stands over the columns least of all beneficial; *M* over those most of all beneficial. In both the columns marked *S*, the harvest moon is fartherest south, or lowest in the orbit; in those marked *N*, it is fartherest north or highest in the orbit. Some years come so near a mean between the least and most beneficial, as scarcely to belong to either. Such is the year 1815.

HARVEST MOON OF THE 19TH CENTURY.

Years least beneficial.

N.				L.				S.	
1806	1807	1808	1809	1810	1811	1812	1813	1814	1815
1825	1826	1827	1828	1829	1830	1831	1832	1833	
1844	1845	1846	1847	1848	1849	1850	1851	1852	
1862	1863	1864	1865	1866	1867	1868	1869	1870	
1881	1882	1883	1884	1885	1886	1887	1888	1889	
1899	1900								

Years most beneficial.

S.				M.				N.	
				1801	1802	1803	1804	1805	
1816	1817	1818	1819	1820	1821	1822	1823	1824	
1834	1835	1836	1837	1838	1839	1840	1841	1842	1843
1853	1854	1855	1856	1857	1858	1859	1860	1861	
1871	1872	1873	1874	1875	1876	1877	1878	1879	1880
1890	1891	1892	1893	1894	1895	1896	1897	1898	

CHAPTER VI.

THE TIDES.

Kepler was the first, who discovered, that the attraction of the sun and moon was the cause of the tides. But a "hint being given, the immortal Sir Isaac Newton improved it, and wrote so amply on the subject, as to make the theory of the tides in a manner quite his own, by discovering the cause of their rising on the side of the earth opposite to the moon.— For Kepler believed, that the presence of the moon occasioned an impulse, which caused another in her absence."

Simply the attraction of the great celestial bodies does not cause the tides; but the attraction of the nearest part of the terraqueous globe more forcibly than the opposite part. It is well known in gravitation, that in any body the power of attracting distant bodies decreases, as the squares of the distances increase. Hence the water next to the moon or sun is attracted more than the centre of the earth; and the centre of the earth, more than the water on the opposite side.

In the tides caused by the moon, the points on the surface of the earth directly under and opposite to the moon may be considered as the centres of highest elevation, and 90° from these as the circle of low water.

The tide on the side of the earth opposite to the moon has caused wonder and perplexity to almost every tyro in astronomy. But the explanation of it is not difficult. We are to consider, that, when the distance between the surface of the water and the centre of the earth is increased, the water will rise on the adjacent land; the effect being the same, if the centre be drawn from the surface, as if the surface be drawn from the centre.

The earth exclusive of the water being a solid body, moves as its centre. Suppose three particles of matter; one on the surface of the earth next to the moon, another at the centre of the earth, and a third on the opposite surface. The particle next to the moon being most attracted will have a tendency to rise from the centre, and the central particle, and with it the body of the earth, to recede from that on the opposite surface.

If the whole external part of the globe were water without soundings, the unequal attraction would produce the tides, but not perceptible, as in the present case, a rise upon the land being the means of admeasurement.

Let *N E O E* be the earth; *C* the centre, *M* the moon; *N* the point on the earth's surface next to the moon; (*Plate VII, Fig.* 1.) *O* a point on the opposite surface, *EE* the circle of low water. The attraction of the moon, *M*, being unequal at the different parts, the water from the circle *EE*, on the side next to the moon, is attracted more than the centre, *C*, and *C* more than the water on the opposite side; the water therefore will rise on the earth at *N*, increasing the distance of the surface from the centre, *C*. By the same principle, *C* will be attracted from the surface next to *O*, enlarging the distance and leaving the water, which being farther from the centre is higher to the spectator; high and low in this case always relating to the distance from the centre.

The motion of the earth and moon round a common centre, has by some been assigned as another cause of the tide opposite to the moon. In the revolution of the two bodies, the side of the earth most remote from the moon must move faster than the other side, and the water, endeavouring to escape, must rise towards the highest parts, which in this case is the point opposite to the moon. Though this may have some effect, the unequal attraction is without doubt the principal cause.

The tides travel with the moon; consequently having her declination and the declination opposite, they revolve round the earth. Every place, therefore, below the polar circles, in its diurnal rotation, must have two tides in about 24 h. 50 m. 28 s.

When the moon is in the equator, every place from pole to pole, on the globe, has its regular return of tides; for the circle of low water extends from pole to pole. The two tides equally extend to the poles, and, at places distant from land, return at equal intervals.

As the moon moves towards either tropic, the circle of low water retires from the poles towards the polar circles, where it arrives, when she arrives at the tropic. (*Plate VII Fig 2 and 3.*) Each pole must then be in flood tide, increasing as the moon increases in declination, and highest, when she is at the tropic. As she returns to the equator, the tides ebb at the poles, where it becomes low water when she passes the equinoctial. Each pole therefore, has two tides only, in a revolution of the moon; and full sea returns at intervals of about 13⅝ days.

While the circle of low water is distant from the poles, places in any parallel, touching that circle have but one tide, in a rotation from the moon, to the moon again. Places above that circle have, in the same time, but one, and that a partial tide, while all below its highest point, have two succeeding tides. The extent of single tide from either pole is at all times equal to the moon's declination.

When the moon is in the equator, the tides return at equal intervals. But when she is in any degree of declination, places on each side of the equator, which in their diurnal rotation cut the circle of low water, have unequal duration of ebb and flood, or of time between high and low water, in different parts of the lunar day ; and more unequal as farther distant from the equator. The intervals between high and low water remain equal at the equator, whatever may be the moon's declination.

Places in the northern hemisphere have the highest tides, when the moon is above the horizon in her north declination ; (*Plate VII. Fig* 2 *and* 3,) but the opposite tides, the highest, when she is in south declination. The whole is reversed in the southern hemisphere.

The tide raised by the moon's attraction is greater on the side of the earth next to her, than that on the opposite side, the semi-diameter of the earth bearing a greater proportion to the shorter distance.

The tide is not at its greatest height in the open sea, till after the moon has passed the meridian, above or below the horizon ; because the water, having obtained a direction, continues it, till prevented by external force ; and because the attraction of the moon, immediately after she has passed a place, may be resolved into two forces, one of which impels the water to that place. [*Enfield, Book II. Chap. III. Prop.* 16] This is similar to many occurrences. Thus the heat of the day is most intense sometime after the sun has passed the meridian ; and the extreme heat of summer, after the summer solstice.

The inclination of the moon's orbit to the ecliptic affects, in some degree, the theory of the tides. On this account the highest elevation of water is sometimes more than 5° above the tropics ; and the region of single tides extends as much below the Arctic and Antarctic circles.*

* The theory of the tides, so far as dependant on the moon's influence, may be made plain by a common globe. Imagine the circle of low water directly under the horizon, and the eminences of high water 90° distant. When the poles are placed in the horizon, the effect of the moon passing the equator may be considered, when every place has two tides in a revolution from the moon to the moon again. Elevate the north or south pole about 23 1-2°, the horizon will extend from the Arctic to the Antarctic circle, and represent low water, when the moon is in either tropic. Turn the globe round in the different positions, and the

To avoid confusion, the tide, raised by the moon, has been considered separately. But, as before stated, the sun also raises a tide, which increases or diminishes that caused by the moon; by coinciding with it, or falling into the intervals.

The sun attracts the earth more powerfully than the moon; but has much less influence in raising tides, the semi-diameter of the earth being less, in proportion to the greater distance. This may be made plain, by contemplating small numbers.—Thus, the difference between 99 and 100 is the same as between 9 and 10, or 1 and 2, but the proportional difference is much less.

By the influence of the sun, the tides are earlier, when the moon is in her first and third quarters; later, in her second and fourth. For in the former case, the tide of the sun, precedes that of the moon; in the latter, succeeds and retards the lunar tide. At the conjunctions, the tides raised by the sun, coincide with those of the moon, (*Plate VII. Fig.* 4.) forming the highest, called *spring tides.* At the quadratures, the tides caused by the sun, diminish those of the moon, and form the lowest, called *neap tides.* (*Fig.* 5.) The tides happening at the change and full, about the equinoxes, when both luminaries are in the equator, are higher than those of other seasons; because the equatorial diameter of the earth is longer than any other, the attraction of the sun and moon, on the different parts of the earth is most disproportioned, when they are in the direction of that diameter, or in the plane of the equator; because the highest elevation of water is on the equator, where the diurnal motion of the earth is the greatest; and because the tides extending from pole to pole, are met directly by every part of the earth in its diurnal rotation.

When the moon is in perigee, she produces a higher tide, than when she is in apogee. The sun also produces the highest tides in winter, being then nearest the earth. The

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manner, in which places in every latitude must meet the tides, may be easily considered. If the moon were stationary at either pole, though the water would be attracted and elevated, no succession of tides would occur.

highest tides known are those, which happen about the change or full, a little before the vernal and after the autumnal equinox ; all the causes then, in whole or in part, concurring to produce the greatest effect.

Lakes and small seas have not the extent of water necesry for perceptible tides. The Mediterranean and the Baltic seas, though they communicate with the ocean, are not only too small in themselves ; but have straits too narrow to admit an influx of water sufficient for tides of any considerable height.

The preceding system of the tides must correspond to general theory, and, in a great measure, coincide with observation ; the following remarks, of Mr. Ferguson, however, are entitled to much consideration.

"It is not to be doubted, but that the earth's quick rotation brings the poles of the tides nearer to the poles of the world, than they would be, if the earth were at rest, and the moon revolved about it only once in a month ; for otherwise the tides would be more unequal in their heights and times of their return, than we find they are. But however the earth's rotation may bring the poles of its axis and those of the tides together ; or how far the preceding tides may affect those, which follow, so as to make them keep up nearly to the same heights and times of ebbing and flowing, is a problem more fit to be solved by observation than by theory."

Were the surface of the globe entirely water of considerable depth, the tides might always return according to theory. But the case is very different. Islands and continents, straits and shoals, shores, channels, winds and a variety of other causes affect, and sometimes materially alter, the height and return of the tides in different places. These may be considered as exceptions, the preceding theory, the general principle.

The air being a fluid surrounding the earth, and extending much higher than the water, is more unequally attracted in different parts, by the great heavenly bodies, and, moving without obstruction, must be subject to tides more extensive and higher than those of the ocean.

The vast utility of the tides must be contemplated with admiration by every reflecting mind. They are greatly useful in agriculture and navigation. But this is lost in the far more extensive benefit to health and even to life. Were it not for the action of the tides and saltness, what would the ocean be, but a vast reservoir of contagion and death? Infinite wisdom and goodness are displayed, in giving such inconceivable power of benefiting us, to bodies immensely distant.

CHAPTER VII.

SECTION I.—ECLIPSES.

An *eclipse* is a total or partial obscuration of a heavenly body.

All the planets of the solar system are in themselves opaque, and shine only by reflecting the sun's light. Hence dark shadows are cast on the side not illuminated. These shadows are but privations of light in the space hid from the sun. (*Plate VII*, *Fig* 6.) They are in the form of vast cones extending into the heavens.

If the earth were as large or larger than the sun, its shadow would be co-extensive with the solar rays; and would at times eclipse the other primary planets. But this has never been known. Mars, though often in opposition to the earth, never falls into its shadow. This must therefore terminate before it reaches that planet.

The primary planets can be eclipsed by their secondaries only; and the secondaries, by their primaries. The earth's shadow eclipses the moon; the moon's shadow the earth;—eclipses of the sun, as they are called, being more properly eclipses of the earth. Sanctioned by long established usage, however, the term "eclipses of the sun" will be retained.

The semi-angle of the earth's shadow at the apex, is equal to the apparent semi-diameter of the sun at the earth, minus the sun's horizontal parallax.

For in *Plate VII*, *Fig.* 6, let *A B E* represent the earth's shadow ; *A B C* the semi-angle of the shadow ; *D A S* the semi-diameter of the sun, as seen from the earth ; *A S C* the sun's horizontal parallax. The angle *D A S* is equal to the angle *A S C*+*A B C* *Euclid*, *B. I*, *Prop.* 32. From each of these equals take the angle *A*, *S*, *C*, the remainders are equal, viz. the angle *A B C* is equal to the angle *D A S*—*A S C.*

This being known, the extent of the shadow may be easily found by trigonometry. It is when longest about 219 semi-diameters of the earth ; on a mean, about 216 such semi-diameters.

The extent of the earth's shadow may be found by subtracting the diameter of the earth from the diameter of the sun, and saying, as the difference is, to the distance of the earth from the sun ; so is the diameter of the earth, to the extent of the shadow. Using the semi-diameters will produce the same result.

If the diameters of the sun and earth be taken as in the general table, the extent of the shadow by this computation will be extremely near the same as by trigonometry, the mean distance 217 semi-diameters, equal to 864,094 miles.

If the moon revolved in the plane of the ecliptic, there would be an eclipse at every full or change. But her orbit being inclined to the plane of the ecliptic, in an angle of 5° 9′ 3″, subject to a small variation, an eclipse can happen but when she is in or about one of her nodes. (*Plate VII* *Fig.* 8.) In every other part of her orbit, she is either too high, or too low, to eclipse the sun, or to be eclipsed by the earth. The limit is greater in solar eclipses than in lunar. For if the moon be within about 17° of either of her nodes at the change, there will be an eclipse of the sun. But she must be within about 11° of one of the nodes for her to fall into the earth's shadow, and be herself eclipsed. The greatest solar ecliptic limit, according to Mr. Ferguson's tables, is 18° 11′, the least, 16° 28′ ; the greatest lunar, 11° 51′, the least, 10° 11′. This is a little different from his own statement.

An eclipse of the moon is *partial*, when a part only of her disk is covered; *total*, when the whole disk passes through the shadow; *central*, when the centre of the disk passes through the centre of the shadow.

The moon will be partially eclipsed at the full, if her latitude be greater than the difference, but less than the sum of her own semi-diameter and that of the earth's shadow, at the place of her ingress.

The semi-diameter of a section of the earth's shadow at the moon, subtends an angle at the earth, equal to the sun's horizontal parallax added to the moon's, minus the sun's semi-diameter.

Let *A B D* (*Plate VII. Fig.* 14.) be the earth, *C* its centre, *A G D* the earth's shadow; *F E* the semi-diameter of that circle or section of the shadow, where passed by the moon in a lunar eclipse. The angle *A F C* is the moon's horizontal parallax; *F C E* the angle, which a semi-diameter of the section subtends at the earth.

The angle *A F C* is equal to the angle *F C E* and *F G E* as in the problem from Euclid cited in figure 6; therefore the angle *F C E* is equal to the angle *A F G*—*F G E*; but the angle *F G E* is equal to the semi-diameter of the sun, diminished by the sun's horizontal parallax, as before proved in this plate, figure 6. Add the sun's horizontal parallax to *A F C* the sum is the moon's horizontal parallax added to that of the sun; and add the sun's horizontal parallax to the angle *F G E* the sum is the apparent semi-diameter of the sun. But when the same quantity is added to the subtrahend and to the minuend, the difference remains as before. Therefore the semi-diameter of the section subtends at the earth, an angle equal to the sun's horizontal parallax, added to the moon's, minus the apparent semi-diameter of the sun, which was to be demonstrated.

The moon, when wholly immersed in the earth's shadow, is not invisible; but appears of a dusky red colour, like burnished copper. This phenomenon is probably caused by the refracted rays of the sun, which have traversed the earth's atmosphere, and by it have been turned inward, so as to fall on the moon and render it visible.—*See the account of Mars, Chap. I. Sec.* 3.

All, to whom the moon is visible in her eclipse, see her in the same instant of absolute time.

That hemisphere of the earth, which would be seen as a circle by a spectator at the moon, is called the disk of the earth. The semi-diameter of this is equal to the moon's horizontal parallax.

If at a change the moon's latitude be less than the apparent semi-diameters of the moon and sun and the moon's horizontal parallax added together, there will be a solar eclipse.

The angle subtended by the semi-diameter of the moon's dark shadow at the earth, is equal to the difference of the apparent semi-diameters of the sun and moon.

Let *A D F* be the moon's dark shadow, *A B C* the apparent semi-diameter of the moon, (*Plate VIII*, *Fig.* 13,) *B* a station on the earth, touched by the dark shadow, *B C E* or *B C D* the angle subtended by the semi-diameter of the dark shadow at the earth, *D* the apex of the shadow, and *B D C* taken as the semi-diameter of the sun.* In the triangle *B D C* the side *D B* being produced, the external angle *A B C* as before, (*Plate VII*, *Fig.* 6,) is equal to the two interior and opposite angles, *B C D* *B D C*. The angle *B C D* is therefore equal to the difference between the angle *A B C* and the angle *B D C*: which was to be demonstrated.

The dark shadow is largest, when the moon is in perigee and the earth in aphelion. Sometimes the dark shadow is terminated, before it reaches the earth. In this case, the sun at the centre of an eclipse appears like a luminous ring; (*Plate VII. Fig.* 9.) and the eclipse is called annular. This beautiful phenomenon was seen in some parts of New England, on the morning of April 3, 1791. The dark shadow is shortest, when the moon is in apogee and the earth in perihelion.

The eclipses of September 17, 1811; February 12, 1831; and September 18, 1838, may be enumerated as annular eclipses of the present century within the United States.— The total eclipses computed for the same time are that of June 16, 1806, and that of August 7, 1869.†

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* See Enfield, Astronomy, Part I. Book VII, Chapter V, Prop. 97, Lemma.

† It will be seen in the century, and also by inspection of the tables of the sun's and moon's diameter, that annular eclipses are more common than those which are total.

The penumbra is the moon's partial shadow. This is like the frustrum of a vast cone, extending indefinitely into the heavens ; the least diameter of which is at the moon.—Let *S* be the sun, (*Plate VII, Fig.* 7,) *M* the moon, *E* the earth, *M, E* the moon's dark shadow, the partial shadow, *a b c d* will then be the penumbra. The darkness of the penumbra decreases as it diverges from the dark shadow of the moon. The dark shadow and penumbra in solar eclipses appear to pass over the earth nearly from west to east ; except at the polar regions, where they sometimes appear to pass in an opposite direction.

The whole number of eclipses in any one year is never less than two, nor more than seven ; when two, both are of the sun ; when seven, four are of the sun, three of the moon.

It is stated in some books, that when there are seven eclipses in a year, five are of the sun. So far as I have examined, such an event appears barely possible. Should it ever happen, two of them must be very slight, the penumbra just touching the pole.

The line of the moon's nodes is constantly moving backwards, or from east to west, at the rate of 19° 20′ 29″, in a tropical year ; making a complete revolution in 18y. 223d. 20h 13m. 32s. In a year of 365 days, it moves 19° 19′ 43″, making a revolution in 18y 224d. 4h. 53m when leap year is 4 times taken ; in 18y. 223d. 4h. 53m. when leap year is 5 times included. The retrograde motion of the nodes brings either of them round to the sun in 346d. 14h. 52m. 14s. on a mean. Half of this time will intervene between the different nodes passing the sun. When eclipses happen at the ascending node, in about 173 days after, other eclipses may be expected at the descending node ; and again, after an elapse of the same time, at the ascending ; and thus in rotation.

When the sun and moon have been in conjunction with one of the moon's nodes, they will, after 223 mean lunations. be in conjunction again, within 28′ 12″ of the same node. This forms a regular period of eclipses. It is completed in 18y.

10d. 23h. 3m. 51s. reckoning according to tropical years; but in common calendar, 18y. 11d. 7h. 43m. 19s. when leap year is 4 times taken; 18y. 10d. 7h. 43m 19s. when leap year is 5 times included. Each eclipse has a regular series of returns. Those which happen at the ascending node, first strike the earth at the north pole, and, moving a little southerly at each return, pass off at the south pole. Afterwards it will be more than 12,000 years before they will begin a new series. But the absence of an eclipse will scarcely, if ever, exceed 12,548 years. Eclipses, which happen at the descending node, begin at the south pole, and retire at the north. The same number of eclipses commence at one pole as at the other. The commencement of a series may be accelerated or retarded about one hundred years by the irregular motion of the earth and moon. An eclipse may visit the earth but 70 times in one series. It will not surpass 77 times. In the one case it will occupy about 1262 years; in the other about 1388. To find how many times an eclipse will happen in the same course, divide twice the ecliptic limit reduced by 28′ 12″. The ecliptic limit varies as we have seen, from 16° 28′ to 18° 11′. The long interval after an eclipse has left the earth, till it will again return, may be found by subtracting twice the ecliptic limit from 360°, dividing the remainder by 28′ 12″, and multiplying the quotient by 18y. 10d. 23h. 3m. 51s. the time intervening between returns.

The memorable eclipse of June 16, 1806, total to a large part of New-England, happened at the moon's descending node. This eclipse traversed the expansum from the creation till the year 1049, when on the 6th of March, O. S. at 10h. 11m. 39s.* in the morning, it first met the south pole. It has been moving farther north at each return to the present time. It will make its next visit on the 26th of June, 1824, at 6h. 41m. 10s. in the evening.† The extreme circle of the

* To bring these calculations to the meridian of Boston, where the eclipse was total, add 23m. 26s.

† Calculated before the year 1824.

penumbra touching Boston just as the sun sets, the eclipse will be scarcely visible in New-England. At the city of Washington, the sun will go down partially eclipsed.

The dark shadow, after passing over an immense tract of the Pacific ocean, will approach the western shores of North America, and, coasting majestically along by New Albion, California, and other Spanish provinces, will set near Acapulco in Mexico.

The next return of this eclipse will be on the 8th of July, 1842, at 2h. 2m. 2s. in the morning. It will of course be invisible in the United States; but will be total over a wide extent of the eastern continent. *For its next return in* 1860, *see projection, Plate IX.* Its last return in the present series will be on the 11th day of May, in the year 2347, at 7h. 7m. 10s. in the morning, according to the Gregorian calendar.

This eclipse, having obscured the earth in some part 72 times, will then leave it, not again to return at the same node till after a long absence of more than 12,000 years. It is observable, however, that it may be considered as the same eclipse, which in half that time must pass through a series at the other node.

If the earth and moon moved in circular orbits, this eclipse would have first touched the earth, on the 22d day of January 976, O. S.; and would leave it April 6th, 2293, N. S.

The moon's dark shadow, when longest, and when falling directly on the earth, will extend about 107 miles. But when, as in most cases, it falls obliquely, it may extend much farther. When falling most obliquely, the exterior edge just touching the earth's disk, it may in an elliptical form extend more than 900 miles.

To find the extent, the angle, which a semi-diameter of a circle or section of the shadow at the earth subtends at the moon, must be first found, by subtracting the apparent semi-diameter of the sun from that of the moon. Then by trigonometry, as radius is to the distance of the moon from the earth, at the time; so is the tangent of the angle subtended by the semi-diameter of the circle of the shadow, where cut by the earth, to the extent of that semi-diameter. This doubled will be very nearly the extent. But more accurately, it will be a sine of half the number of degrees covered by the shadow, on the earth's surface; the semi-diameter of the earth being taken as radius. Or it may be found very nearly by saying, as the moon's horizontal parallax is to the difference of the apparent semi-diameters of the sun and moon; so is the earth's semi-diameter in miles, to half the extent of the shadow, where cut by the earth. This may also be taken as the sine of the degrees on the earth's surface.*

The extent of the penumbra upon the earth is very different at different times; not only on account of the varying distance of the heavenly bodies, but of its striking the earth, more or less obliquely. The tables make it, when least, about 4500 miles; when most, a little more than 7,000. It is least, when it falls directly on the earth, the moon being in perigee and the earth in aphelion; most, when the moon is in apogee and the earth in perihelion, and the moon's latitude such, that the partial shadow extends across the earth's disk, the diameter of its section forming a chord to the disk.

To find the extent, say, as the moon's horizontal parallax, is to the semi diameter of the earth; so is the semi-diameter of the penumbra, to the miles in that semi-diameter;—which may be taken as a sine of the degrees on the earth's surface, the earth's semi-diameter being radius. Double the degrees, gives the extent of the penumbra. This is subject to a very trifling error. It may be found, like the dark shadow, by the distance of the moon.

The extent of the penumbra and dark shadow in any parallel of latitude may be found in the same manner, the proportion being made between radius and the co-sine of the latitude passed over by the moon, and found by the moon's latitude. The extent, when the penumbra and dark shadow are partially upon the earth, may be found by considering it as a

* Mr. Ferguson made the dark shadow extend 180 miles. He must have been mistaken, if he computed from his own tables. The tables of Ewing and Enfield make it about 140 miles.

versed sine of the circle passed over ; when wholly, but obliquely on the earth, it may be considered as a part of a versed sine, and the remainder easily known.

Total darkness in an eclipse of the sun will never, according to the tables of this work, continue in one place more than 5′ 32″. According to those of Enfield, the duration will be a little longer. Several authors state this duration at three minutes or about three minutes ; but this is short of the truth. The total darkness was considerably short of the maximum in the June eclipse of 1806 ; yet at Atkinson, New-Hampshire, the author, carefully observing its duration in that eclipse, found it 4′ 20″. Robert B. Thomas, the author of the Farmer's Almanack, at Sterling, Massachusetts, probably nearer the centre of the shadow as it passed, found the time of that total darkness, 4′ 45″. Mr. Thomas, in his almanack for 1806, inserted "Duration of total obscurity, $2\frac{1}{4}$′." But in 1807, he corrected himself by a note at the end of his account of eclipses for that year. "The total obscurity of the sun, in the great eclipse of June 16, 1806, was observed to be much longer than given in this almanack, which was on account of there being no allowance, made for the earth's diurnal or easterly motion at the time of the obscurity. The duration of obscurity was observed to be at Sterling, Mass. 4′ 45″."

In ascertaining the duration of total darkness, allowance must be made for the motion of the place of observation by the turning of the earth on its axis. Hence the duration is longest in an eclipse nearly or quite central, the sun and moon on or near the meridian, the motion of the observer and of the moon's shadow in the same or nearly the same direction.

The duration may be found by comparing the moon's horizontal parallax with her horary motion from the sun ; for, as the moon's horizontal parallax is to the semi-diameter of the earth ; so is the moon's horary motion from the sun, to the miles passed by the shadow at the earth. The sixtieth part of this is the distance passed on the earth's surface in a minute. For though strictly it is the sine of the angle at the centre of the earth, in so short a distance the sine and arch may be taken as equal. A meridian on the earth, and, of course, an observer, passes from the sun one fourth part of a degree in a minute. Subtract this from the distance passed in the same time by the shadow, the difference is the motion of the shadow from the observer, allowance being made for obliquity in the motions. Hence, by knowing the miles passed in a minute and the breadth of the shadow, we may compute how long it will be in passing by a particular place.

How the duration of total darkness, may be found geometrically in projecting solar eclipses, may be seen in the directions for projecting the eclipse of July 18, 1860. *See section V, of this chapter.*

When the moon changes in one of her nodes, the centre of the penumbra passes over the centre of the earth, making the largest general eclipse. The duration however varies a little with the distance of the moon from the earth, and a very little with the distance of the sun. It is longest when the moon is in apogee and the earth in its perihelion, being then about 6h. 13′. The mean duration of such a general eclipse is about 5h. 46′. The motion of the moon varies with her distance from the earth, being slowest, when she is fartherest distant. This makes an apogeal eclipse a little longer than a perigeal.

The general eclipse begins, when the penumbra first touches the earth; ends, when it leaves the earth. An eclipse begins at any particular place, when the penumbra first touches it; ends, when the penumbra leaves that place.

The position of the earth's axis, as seen from the sun, or moon, at the change, greatly affects solar eclipses. This will be too apparent in projecting those eclipses to need explanation. Compare the eclipse in the projection, *Plate IX*, with the same eclipse on June 16, 1806.

ECLIPSES VISIBLE AT THE CAPITOL IN WASHINGTON-CITY, AND GENERALLY THROUGH THE UNITED STATES.

As the ingenious student generally wishes to anticipate eclipses, but often finds a difficulty in ascertaining, when those most suited to his genius may happen, the following catalogue was formed for his assistance. The time set to solar eclipses is the middle of each eclipse, as seen from the Capitol; to lunar, the minute of opposition. Both are reduced to apparent time.

Year	Species	Month	D	H	M	A.P.M.	NOTANDA.
1800	☽	Oct	2	5	0	P M	Small. Visible in N. E.
1801	☽	March	30	0	16	A M	Total
	☾	Sept.	22	2	20	A M	Total.
1802	☾	March	19	5	8	A M	
	☽	Sept.	11	5	40	P M	
1803	☉	Feb.	21			P M	Sun goes down partially eclipsed.
1804							
1805	☽	Jan.	15	3	29	A M	Total.
1806	☽	Jan	4	6	43	P M	
	☉	June	16	10	58	A M	Total in N. E.
1807	☽	Nov.	15	3	10	A M	
1808	☽	May	10	2	35	A M	Total.
	☽	Nov.	3	3	23	A M	Total.
1809	☉	April	14	4	45	P M	
	☽	April	29	7	46	P M	
	☾	Oct.	23	4	18	A M	
1810							
1811	☽	March	10	1	8	A M	
	☽	Sept	2	5	38	P M	Moon rises partially eclipsed.
	☉	Sept.	17	2	4	P M	Annular.
1812	☽	Feb.	27	0	52	A M	Total.
1813	☽	Feb.	15	3	39	A M	
	☾	Aug.	11	9	49	P M	
1814	☽	Dec	26	6	9	P M	
1815	☉	July	6			P M	Sun goes down eclipsed.
1816	☾	June	9	8	10	P M	Total.
	☽	Dec.	4	3	4	P M	Rises eclipsed in N. E. scarcely visible at Washington.
1817							
1818	☽	April	20	7	5	P M	
	☽	Oct.	14	0	30	A M	
1819	☉	April	24			A M	Sun rises eclipsed.
1820	☉	Sept.	7	6	56	A M	
	☾	Sept.	22	1	46	A M	
1821	☉	Aug.	27	8	49	A M	
1822	☾	Feb.	6	0	23	A M	
	☉	Feb.	21	4	6	P M	
	☾	Aug.	2	7	14	P M	
1823	☽	July	22	10	19	P M	Total.
1824	☾	Jan.	16	3	53	A M	
	☉	June	26			P M	Sun goes down slightly eclipsed.
	☽	July	10	11	12	P M	
1825	☉	Dec.	9			P M	Goes down eclipsed.
1826							
1827	☽	May	11	3	20	A M	
1828							
1829	☽	Sept.	13	1	36	A M	
1830	☽	March	9	8	32	A M	Visible in Missouri Territory.
	☾	Sept.	2	5	37	P M	Total Moon rises eclipsed.
1831	☉	Feb.	12	0	35	P M	Annular over a large southern section of the Union.
	☽	Aug.	23	4	57	A M	

Year	Species	Month	D.	H.	M.	A.P.M.	NOTANDA.
1832	☉	Feb.	1	5	10	P M	Visible in the western parts of the Union.
	☉	July	27	7	34	A M	
1833	☽	Jan.	6	2	48	A M	
	☽	July	1	7	32	P M	About total.
	☽	Dec.	26	4	30	P M	Total.
1834	☽	June	21	3	13	A M	Total.
	☉	Nov.	30	2	38	P M	
	☽	Dec.	15	11	50	P M	
1835							
1836	☽	May	1	3	6	A M	
	☉	May	15	8	14	A M	
	☽	Oct.	24	8	22	A M	Visible in Missouri Territory.
1837	☽	Oct.	13	6	29	P M	Total.
1838	☽	April	9	9	0	P M	
	☉	Sept.	18	4	32	P M	Annular in Virginia.
1839							
1840	☽	Aug.	13	2	9	A M	
1841	☽	Feb.	5	8	49	P M	Total.
	☽	Aug.	2	4	49	A M	Total.
1842	☽	July	14	5	43	A M	Visible at Astoria and other western regions.
1843	☽	Dec.	6	7	7	P M	Very small.
1844	☽	Nov.	24	6	51	P M	Total.
	☉	Dec	9	4	19	P M	Small.
1845	☉	May	6			A M	Sun rises a little eclipsed.
	☽	Nov.	13	8	7	P M	
1846	○	April	25	0	6	P M	
1847							
1848	☽	Sept.	13	1	23	A M	Total.
1849	☽	March	8	7	48	P M	
1850							
1851	☽	July	13	2	8	A M	
	☉	July	28	8	11	A M	
1852	☽	Jan.	7	1	3	A M	Total.
	☽	Dec.	26			A M	Begins 6h. 28m.
1853	☽	Jan.	21	1	3	A M	Small.
1854	☽	Nov.	4	4	22	P M	Very small. Visible in N. E.
1855	☽	May	1	11	6	P M	Total.
	☽	Oct.	25	2	42	A M	Total.
1856	☽	April	20	4	10	A M	
	☽	Oct.	13	6	12	P M	
1857							
1858	☽	Feb	27	4	55	P M	Moon rises partially eclipsed.
	○	March	15	6	16	A M	
1859	☽	Feb.	17	5	36	A M	Total.
	☉	July	29	5	44	P M	Small.
1860	☽	Feb.	6	9	17	P M	
	☉	July	18	7	55	A M	
1861	☽	Dec.	17	3	9	A M	
	☉	Dec.	31	7	45	A M	
1862	☽	June	12	1	18	A M	Total.
	☽	Dec.	6	2	43	A M	Total.
1863	☽	June	1	6	30	P M	Total. Moon rises eclipsed.
	☽	Nov.	25	4	21	A M	
1864							
1865	☽	April	10	11	29	P M	Very small.
	☽	Oct.	4	5	50	P M	Very small.
	○	Oct.	19	10	27	A M	
1866	☽	March	30	11	30	P M	Total.
1867	☽	March	20	3	45	A M	

Year	Species	Month	D. H. M.	A. P. M	NOTANDA.
	☽	Sept.	13 7 30	P M	
1868					
1869	☽	Jan.	27 8 21	P M	
	☉	Aug.	7 6 5	P M	Total over a southern section of the Union.
1870					
1871	☽	Jan.	6 4 9	P M	Moon rises partially eclipsed.
1872	☽	Nov.	15 0 29	A M	Very small.
1873	☽	May	12 6 23	A M	Commences 4h. 34'. Total in the western states.
1874	☽	Oct.	25 2 37	A M	Nearly total.
1875	☉	Sept.	29 6 12	A M	
1876	☽	March	10 1 5	A M	
	☉	March	25 4 45	P M	Small.
1877	☽	Aug.	23 6 2	P M	Total. Moon rises eclipsed.
1878	☽	Feb.	17 5 58	A M	
	☉	July	29 5 35	P M	
	☽	Aug.	12 7 3	P M	
1879					
1880	☉	Dec	31 7 42	A M	
1881	☽	June	12 1 56	A M	Total.
1882					
1883	☽	Oct.	16 2 8	A M	
1884	☽	April	10 6 47	A M	Total in the western parts of the Union.
	☽	Oct.	4 5 14	P M	Visible and total after the sun sets.
1885	☉	March	16 1 28	P M	
	☽	Sept.	24 2 56	A M	
1886	☉	March	5	P M	Commences about sun set. Visible in the western states.
	☉	Aug.	29 6 23	A M	Very small.
1887	☽	Feb.	8 5 4	A M	
1888	☽	Jan.	28 6 6	P M	Total.
	☽	July	23 0 35	A M	Total.
1889	☉	Jan.	1	P M	Penumbra touches Washington about sun set. Visible in the western states.
	☽	Jan.	17 0 18	A M	
1890					
1891	☽	Nov.	15 7 36	P M	
1892	☽	May	11 6 0	P M	Visible after the sun sets.
	☉	Oct.	20 1 40	P M	
1893					
1894	☽	Sept.	14 11 24	P M	
1895	☽	March	10 10 28	P M	Total.
	☽	Sept.	4 0 49	A M	Total.
1896	☽	Aug	23 1 55	A M	
1897	☉	July	29 9 45	A M	
1898	☽	Jan.	7 7 16	P M	Small.
	☽	Dec.	27 6 37	P M	Total.
1899	☽	Dec.	16 8 34	P M	
1900	☉	May	28 8 40	A M	

It will be seen, that some eclipses are included in the preceding catalogue, which are not visible at the Capitol. A few, however, visible in distant parts, only are not inserted.

SECTION II.

SOME EXPLANATION OF THE TABLES USED IN CALCULATING ECLIPSES.

The *mean* place and motion of a planet at any time, are what the place and motion of that planet would be, if its movement were uniform in a circle.

A *mean lunation* is the time intervening between one change of the moon and another, calculated in mean motion.

The *mean anomalies* of the sun and moon, are their mean distance from their respective apogees reckoned in degrees, minutes and seconds.*

These anomalies must have been obtained at first by accurate observation at long intervals, and dividing between them. The sun's distance from the moon's ascending node must have been first found in the same manner.

In these and other astronomical calculations, when the signs become 12 or more, 12 or a multiple of 12, are rejected, and the remainder, if any, used as the true number ; because 12 signs complete a circle. The distance passed from the apogee and the moon's node, are always taken, and not the remaining distance, however small.

Table I, contains the mean time of new moon, in March, the anomalies of the sun and moon, and the sun's distance from the moon's ascending node for the present century. The year is begun in March, to avoid the inconvenience otherwise arising from bissextile. A year in this table includes two months of the succeeding year. The numbers for 1800 were taken from other tables, originally formed from observation.†

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* No inconvenience arises from some of these calculations being made on the supposition, that the sun moves round the earth, as he always appears in the ecliptic directly opposite to the earth.

† These tables were calculated for the meridian of the capital in Washington-city, lon. 76° 55′ 30″ 54‴. W. of Greenwich; but may be used for any other place, by applying the numbers in table 16, the table for changing longitude into time.

The numbers for succeeding years were formed by adding 12 lunations from table second and rejecting 365 days for a common year, and 366 for a leap year. But when the new moon in March happens before the 11th day of the month, 13 mean lunations were added. On the Gregorian principle, the year 1900 was not considered bissextile. This table may be used for old stile, by deducting 12 days from the given time. If the days of the table in March be less than 12, a lunation with its annexed numbers must be added before the subtraction is made.

TABLE II, contains 13 mean lunations. The exact time of one mean lunation, the mean anomalies of the sun and moon, and the sun's mean distance from the moon's ascending node, are placed in the first line. These are doubled for two lunations. The succeeding numbers are formed by adding a lunation with its anomalies and distance from the node to the preceding numbers in each case. The half lunation is subjoined for the purpose of calculating fulls.

TABLE III, was formed by deducting the time of new moon in March, 1800, with its anomalies and distance from the node from the last new moon in March, 1900, with its annexed numbers. But one day was deducted from the new moon in March, 1900, from table second, as here it must be reckoned bissextile. By this deduction is obtained the difference for a complete century of Julian years. By adding, the table was carried to 5,000 years, and doubled for 10,000, a lunation being deducted, when the days exceed 29.

Its application is in calculating eclipses for any time before or after the 19th century. It may be used for any number of thousand years. Suppose 6000 required; add the numbers in the line against 1000 to those of 5000. By additions and multiplications, this table may be carried to any number of centuries at pleasure.

TABLE IV, contains the number of days passed from the first of March, at any time of the year.

These four first tables would be sufficient for calculating eclipses at any time, if the motion of the planets were equable. But this is not the case, as before shown. At the apogee and perigee, the place of a heavenly body is the same, as if it moved in a circle ; the anomaly being nothing, or six signs. From the apogee to the perigee, the mean place is before the true ; it is after it, from the perigee to the apogee. When the sun's anomaly is less than six signs, the moon will come round to him sooner, than if the motion of the earth and moon were uniform ; later, when the anomaly exceeds six signs. The greatest inequality, arising from this cause is 3h. 48m. 28s. The sun is in apogee on the 1st day of July ; in perigee, on the 31st of December, at the present time, 1825. When the earth is in its aphelion, the sun is in apogee The aphelion moves in the signs 1′ 2″ in a year ; of course the apogee moves the same.—*See motions of the earth ; see also the anomaly in Table* 10.

The moon's orbit is affected by her distance from the sun, being dilated in winter and contracted in summer. The lunations of winter are therefore longer than those of summer. The extreme difference is 22m. 29s. the lunations increasing in length, while the sun is passing from the apogee to the perigee ; and decreasing while he is returning to the apogee. These equations, arising from the same cause, are united in TABLE V, with the titles, add or subtract.

TABLE VI, was formed to correct the moon's anomaly.—The table of her anomaly is calculated for mean time, and as the time of change or full is altered by the sun's anomaly, it is necessary that her anomaly should be brought to the real time of change or full. If these phenomena happen earlier on account of the sun's anomaly, the moon will not have passed so far from her apogee, as at the mean time. If they happen later, she will have passed farther than at the mean time.

The moon's orbit is more elliptical than that of the earth. Her motion is so unequal, that she is sometimes in conjunction with the sun, or in opposition, 9h. 47m. 54s. sooner or later than she would be by equable motion in a circle. The differences are placed in TABLE VII, with the directions, add or subtract.

TABLE VIII, is founded on the different attractions of the sun and earth, upon the moon at different distances.

TABLE IX, is founded on the obliquity of the moon's orbit to the ecliptic. The principle is explained under equation of time.

TABLE X, was formed for ascertaining the longitude and anomaly of the sun at any given time. These were calculated for the meridian of the capitol in Washington, at the noon of the last day of December, 1799; which are set as the longitude and anomaly for the year 1800. By adding the longitude $11^s\ 29° 45' 40'' 24'''$, and the anomaly, $11^s\ 29° 44' 38'' 24'''$ for each succeeding year of 365 days, and the same increased by a day, the longitude $59' 8'' 19''' 47''''$, and the anomaly $59' 8'' 9''' 36''''$, for bissextile, the table was carried to 1900; and afterwards copied to the nearest seconds. The noon of the first day of January might seem more proper than that of the last day of December. This table was so constructed at first; but on trial, in taking for the days of the months, it was found inconvenient.

For complete Julian years, the motion and anomaly in one year were taken, and carried by additions to complete the table. The use of this part of the table is in calculating the sun's longitude and anomaly for years before or after the nineteenth century.

When the longitude and anomaly of the sun for years less than a century are taken, a requisite number of bissextile years must be included, or the motion for the days deficient, must be added. Without such addition they may not make the complete numbers, as may be seen by adding the numbers for ten years to those of fifty. These will not complete the numbers for sixty without those of an additional day.

The longitude and anomaly of the sun at the noon of the last day of a month are set at the beginning of each succeeding month; so that on the first day of a month the numbers for a day are to be taken. And for any time in a month, the longitude and anomaly are to be sought against the corresponding numbers in the table.

But in using the table for months in bissextile years, a day less than the tabular time sought in January and February must be taken. Accordingly for the first day of January, the numbers for the last day of December preceding, must be used. The sun's mean motion from the moon's node for hours, minutes and seconds is annexed to this table, being frequently useful in the calculation of eclipses.*

TABLE XI, is founded on the elliptical form of the earth's orbit, showing the difference between the mean and true place of the sun. It must be sufficiently obvious to those acquainted with the planetary motions.

TABLE XII, shows the declination of the sun, or how far he is north or south of the equator at every degree of his longitude. The principle may be easily understood by inspecting the ecliptic and equator, as represented on an artificial globe.

TABLE XIII, like table XI, is founded on the elliptical form of the earth's orbit.

The remaining tables will scarcely need explanation to those acquainted with the preceding, and the general principles of astronomy; except the table of proportional logarithms.

TABLE XIX. Proportional Logarithms are artificial numbers. They are deduced from common logarithms and applied either to time or motion. The table may be of any extent according to the pleasure of the former. Dr. Bowditch's table of proportional logarithms is made for three hours. In this case the logarithm of the seconds in three

* A table for finding the moon's longitude is found in some astronomical works. But as this table is long, and its corrections many and rather embarrassing to the student, its insertion here was thought incompatible with the design of this work.—The tables for the four equations used by Ferguson, "give," as stated by President Webber in his appendix to Enfield, "the times of new and full moon with little trouble, and sufficiently true for common use; being rarely above one or two minutes wide of the truth." The tables for the 4 equations in this work are extracted from Ferguson, or formed on his principle.

hours, viz. 10800, is made the foundation of the table. The logarithm of this number is 4.03342. The logarithms of all the intermediate numbers from this number to nothing, being subtracted from this, leave the proportional logarithms set to the numbers. Thus to form the logarithm of 40 minutes, the common logarithm of 2400, the seconds in 40 minutes, viz. 3.38021 is deducted from 4.03342; the remainder 6532 is the logarithm of 40 minutes, the right hand figure being rejected.

In Table XIX, 1° is made the foundation of the table. The seconds in one degree are 3600, of which the logarithm is 3.55630. From this logarithm the logarithm of each second from 1° to nothing is deducted. The remainders form the table.

EXAMPLE.

Required the proportional logarithm of 20 minutes, equal to 1200 seconds.

From log.	1°	3.55630
Take log.	20′	3.07918
Remainder is		47712

Rejecting the right hand figure, it is 4771.

The numbers at the top of the table are minutes, those in the left hand column are seconds. To take the proportional logarithm for any number of minutes and seconds, find the minutes at the head of the table and the seconds in the column on the left hand; against the seconds and under the minutes is the logarithm required.

EXAMPLES.

Numbers.	*Logarithms.*
0′ 25″	21584
1′ 20″	16532
5′ 10″	10649
40′ 8″	1746
55′ 4″	373

To find the minutes and seconds answering to any given logarithm; look for the minutes at the head of the column, and the seconds at the left hand. But if the logarithm be not exactly found in the table, take the minutes and seconds answering to the next greater logarithm.

EXAMPLES.

Logarithms.	*Values.*
7674	10′ 15″
1233	45′ 10″
5382	17′ 22″
343	55′ 26″

Proportional logarithms are of great use in finding a fourth proportional. As in common logarithms, addition and subtraction answer the purpose of multiplication and division in common numbers.

Suppose it required to find how far a meridian of the earth passes from the sun in 35 seconds.

As 4m.	11761
To 1°	0
So 35s.	20122
	—11761
To 8m. 45s.	=8361

An important use of this table is the application of it in astronomical calculations to other tables made for signs and degrees only. To take for minutes and seconds from a table thus made, find the difference between the numbers against the degree given and those against the degree next higher. Then by proportional logarithms, as one degree is to the difference, so are the minutes, or minutes and seconds given, to the answer required, to be added or subtracted, as may be requisite.

EXAMPLES.

In calculating the solar eclipse of July, 1860, the sun's anomaly is 0^s 15° 55′ 24″ for taking the first equation from Table V.

Against 0^s 15° are 1h. 3m. 36s. Subtract this from 1h. 7m. 45s. the numbers against 0^s 16°, the remainder is 4m. 9s.

As	60′	0
To	4m. 9s.	11601
So	55′ 24″	346
To	3m. 50s.	=11947

This added to 1h. 3m. 36s. gives 1h. 7m. 26s. the true first equation.

In the same solar eclipse, the moon's equated anomaly is $4^s\ 6^\circ\ 46', 14'$, the argument for the second equation in Table VII.

Against $4^s\ 6^\circ$, the numbers are 7h. 33m. 36s. From this deduct 7h. 27m. 22s. the numbers against $4^s\ 7^\circ$, the difference is 6m. 14s.

As	60′	0
To	6m. 14s.	9834
So	46′ 14″	1132
To	4m. 48s.	=10966

As the numbers are here lessening with the increase of degrees, this 4m. 48s. must be subtracted from 7h. 33m. 36s. The remainder is 7h. 28m. 48s. the true equation.

In questions where the fourth proportional would exceed 60 minutes, the limit of the table, divide the third number by 2, 3, 4, 10, or any convenient number, and multiply the fourth, when found, by such number, the product is the answer required.

EXAMPLE.

If the hourly motion of the moon in longitude be 32′ 56″, and the moon be 50′ 30″ from the first degree of Aries, in what time will it arrive at that point ? Taking one half the third term, the proportion will be,

As	32′ 56″	2605
To	60m.	0
So	25′ 15″	3750
		—2605
To	46m.	=1154

This doubled is 1h. 32m. the answer.

When two or all the terms exceed the limits of the table, divide all the terms by some convenient number, and multiply the fourth proportional by such number.

EXAMPLE.

If Mercury move 20′ 28″ in two hours, how far will it move in 3h. 20m. ?

Dividing each of the terms by 4, the proportion is,

As	30m.	3010
To	5′ 7″	10692
So	50m.	792
		11484
		—3010
To	8′ 31″	=8474

This multiplied by 4, gives 34′ 4″, the answer.

The numbers at the head of the table may be used for degrees or hours and then those in the left hand column will be minutes.

EXAMPLE.

If 13 hours give 2° 13′, what will 22h. 23m. give ?

As	13h.	6642
To	2° 13′	14325
So	22h. 23m.	4282
		18607
		—6642
To	3° 49′	=11965

This table may be applied to any numbers proceeding in sexagesimal order.

SECTION III.

TO CALCULATE THE TRUE TIME OF NEW OR FULL MOON FOR ANY TIME IN THE 19TH CENTURY.

For new moon, take the mean time of new moon in March, of the year proposed, the anomalies of the sun and moon, and the sun's mean distance from the moon's ascending node from table I. For any succeeding month, take as many lunations as the number of months, reckoning from March, with the anomalies and distance from the node, from table II.— Add these together, the sum will be the mean time of new moon, the mean anomalies of the sun and moon and the sun's mean distance from the ascending node for the month required. Except, rarely, the number of lunations must exceed by one the number of months, a lunation being a little short of a month of 30 or 31 days.

For the full moon in any month, half a lunation, the anomalies and distance, from table II, must be added to the numbers of the change in that month. But if the change happen after the 15th of the month, the half lunation must be subtracted. Rarely two changes or two fulls happen in a month. The number of days thus found must be sought in table IV, under the month. In the same line at the left hand will be the day of the mean change or full. But if the days added fall short of the intended month, another lunation with its attendant numbers must be taken. The day of the month thus found must be set before the hours, minutes, and seconds, the anomalies and distance from the node, before found.

With the sun's anomaly enter table V, and take the first equation for reducing the mean syzygy to the true, making proportions for the odd minutes and seconds as directed in table XIX. Observe in this and other astronomical calculations, if the signs be at the top, the degrees are at the left hand ; if at the bottom, the degrees are at the right. The titles *add* and *subtract* must also be carefully observed in all the tables.

With the sun's anomaly enter table VI, and take the equation of the moon's mean anomaly, applying it according to the directions, add or subtract.

Find the moon's equated anomaly in table VII, and take the second equation of the mean to the true syzygy. This will bring the time sufficiently near, when peculiar accuracy is not required. But for calculating eclipses, subtract the moon's equated anomaly from the sun's mean anomaly.—With the difference, as an argument, in table VIII, find the third equation of the time.

With the sun's mean distance from the node, take the fourth equation from table IX. This will give the time very nearly as shewn by a well regulated clock. To make it agree with the sun, apply the equation for reducing true to apparent time, found in table XVIII.

The use of the tables may be made familiar by a few examples.

EXAMPLE.

Required the true time of new moon at Boston, in July, 1860.

	New moon	☉'s anom.	●'s anom.	☉ from node
	D. H. M. S	S. ° ′ ″	S. ° ′ ″	S ° ′ ″
Time in March, 1860	21 12 0 18	8 19 30 7	0 23 55 50	1 21 30 46
Add four lunations	118 2 56 12	3 26 25 17	3 13 16 2	4 2 40 56
Mean new moon July	17 14 56 30	0 15 55 24	4 7 11 52	5 24 11 42
First equation	— 1 7 26	–4 6 46 14	— 0 25 38	Sun from node
Time once equated	17 13 49 4	8 9 9 10	4 6 46 14	Argument for
Second equation	+ 7 28 48	Arg.3d equa.	Arg 2d.equa	the 4th equa.
Time twice equated	17 21 17 52			
Third equation	+ 4 36			
Time thrice equated	17 21 22 28			
Fourth equation	— 19			
True new moon	17 21 22 9			
For difference of longitude	+ 23 26			
Time at Boston	17 21 45 35			
Equation of time	— 5 49			
Time at B. by sun	17 21 39 46			

Hence the true astronomical apparent time, is July 17th day, at 21h. 39m. 46s; in common reckoning, July 18th, at 9h. 39m. 46s. A. M.

TO CALCULATE THE TIME OF NEW OR FULL MOON IN ANY YEAR OF THE CHRISTIAN ERA BEFORE THE 19TH CENTURY.

From table I, take the mean time of new moon in March with the anomalies and distance from the node of a year of the same number in the century with that proposed. Then from table III, take as many centuries of years, with the annexed numbers, as will reduce the year in the 19th century to the year required. Subtract these from the preceding numbers, the remainder will be the mean time of new moon in March, the anomalies and distance from the node for the proposed year. If the time set to March, of the year in the 19th century be less than the time in the centuries of years taken, a lunation from table II, with the annexed numbers must be added to the time in March. Then subtract as before directed. The remaining process is the same, as in calculating the true time of change or full in the 19th century.

In most calculations for years before or after the 19th century, the old stile is to be preferred, on account of its uniformity. It may be reduced to the new by the subsequent rules in this work.

EXAMPLE.

Required the true time of full moon at Plymouth, Mass. in December, 1620, old stile.

	New moon				Sun's anom.				●'s anoma				☉from node			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″.	S.	°	′	″
Time in March at W. 1820.	13	20	35	8	8	12	21	12	6	24	37	21	11	19	35	46
Deduct two centuries	8	16	21	44	0	6	38	12	5	0	43	27	9	8	54	46
Time in March, 1620	5	4	13	24	8	5	43	0	1	23	53	54	2	10	41	0
Add ten lunations	295	7	20	30	9	21	3	13	8	18	10	4	10	6	42	19
Time in Dec. 12d. deducted	13	11	33	54	5	26	46	13	10	12	3	58	0	17	23	19
Add ½ lunation [for stile	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
Mean full moon	28	5	55	56	6	11	19	23	4	24	58	28	1	2	43	26
First equation	+		50	17	-4	25	17	28	+		19	0				
Time once equated	28	6	46	13	1	16	1	55	4	25	17	28				
Second equation	+	5	13	43												
Time twice equated	28	11	59	56												
Third equation	—		3	26												
Time thrice equated	28	11	56	30												
Fourth equation	+		1	25												
Time 4 times equated	28	11	57	55												
Add for difference of lon.	+		25	26												
Time of full moon at Plym.	28	12	23	21												

Hence the true time at Plymouth, by the clock old stile, was 28d. 12h. 23m. 21s.; in civil calendar, 29th day 0h.23m. 21s. in the morning.

TO CALCULATE THE TRUE TIME OF NEW OR FULL MOON IN ANY YEAR BEFORE THE CHRISTIAN ERA.

Find the time of new moon in March, of the year in the 19th century, which added to the year before Christ, diminished by one, will make complete centuries. Subtract the numbers for those centuries, taken from table III, and proceed as in the other precepts.

EXAMPLE.

Required the true time, in Julian calendar, of new moon in September of the year, that Cadmus brought the letters into Greece, allowing that event to have been in the year before Christ, 1493.

	New Moon				☉'s anoma.				☾'s anomaly				☉ from nod			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
Mean time in March, O. S.	14	7	55	37	8	24	45	42	11	13	44	18	4	10	21	23
Add one lunation [1808	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
	43	20	39	40	9	23	52	1	0	9	33	18	5	11	1	37
Deduct for 3300 years	25	3	2	29	11	23	5	1	1	13	40	59	5	9	22	46
Mean time in March, B. C.	18	17	37	11	10	0	47	0	10	25	52	19	0	1	38	51
Add 6 lunations [1493	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
Mean time in September	11	22	1	29	3	25	24	56	4	0	46	22	6	5	40	15
First equation	—	3	48	41	−3	29	19	42	—	1	26	40				
Time once equated	11	18	12	48	11	26	5	14	3	29	19	42				
Second equation	+	8	12	43												
Time twice equated	12	2	25	31												
Third equation	+		0	20												
Time three times equated	12	2	25	51												
Fourth equation	+			19												
True time by clock	12	2	26	10												

Hence the true time of new moon in September, of that year, at the meridian of Washington, was 12th day, 2h. 26m. 10s. P. M.

TO CALCULATE THE TRUE TIME OF NEW OR FULL MOON IN ANY YEAR AFTER THE 19TH CENTURY.

To the mean new moon in March, of the correspondent year in the 19th century, add the requisite numbers for the centuries intervening, from Table III, and proceed as before; observing to subtract a lunation, should the addition carry the new moon beyond the 31st of March. Except, when the time sought is after March, one lunation less may be added, instead of the subtraction.

EXAMPLE.

Required the true time of full moon at New Orleans, in July, 1976.

	New moon				☉'s anom.				☾'s anoma.				☉ from nod			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
Mean new ○ in March, 1876	24	13	22	21	8	22	21	40	3	5	39	14	0	4	16	46
Add for one century	4	8	10	52	0	3	19	6	8	15	[illegible]1	44	4	19	27	23
Mean time in March, 1976+	29	21	33	13	8	25	40	46	11	21	0	58	4	23	44	9
Add 4 lunations [1 day for stile	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
Mean time in July	26	0	29	25	0	22	6	3	3	4	17	0	8	26	25	5
Deduct ½ lunation	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7
Mean full moon	11	6	7	23	0	7	32	53	8	21	22	30	8	11	4	58
First equation	—	0	31	48	8	21	10	17	—		12	13				
Time once equated	11	5	35	35	3	16	22	36	8	21	10	17				
Second equation	—	9	34	40												
Time twice equated	10	20	0	55												
Third equation	—		4	45												
Time three times equated	10	19	56	10												
Fourth equation	+		1	0												
Time four times equated	10	19	57	10												
Deduct for difference of lon.			52	50												
True time at New Orleans	10	19	4	20												

SECTION IV.

TO CALCULATE THE TRUE PLACE OF THE SUN AT ANY TIME IN THE 19TH CENTURY.

From Table X, take the mean longitude and anomaly for the year, month, day, hour, minute, and second, required; then equate the longitude by the numbers found in Table XI, having the anomaly as an argument, and it will be the true place of the sun for the time.

For any time in the Christian era *before the 19th century*, find the longitude and anomaly for the corresponding time in the 19th century, and deduct the longitude and anomaly set against the intervening centuries. But for time long past the old stile is to be preferred. Add the longitude and anomaly for 12 days to those of the year sought in the 19th century, the sum will be the longitude and anomaly at the commencement of the year, old stile. Then proceed as before directed.

For any time *before the Christian era*, find the longitude and anomaly of the year in the 19th century, which added to the year before Christ, minus 1, will make complete centuries. Deduct the longitude and anomaly for the centuries; and proceed as before.

For any time *after the 19th century;* find the longitude and anomaly for the corresponding time in the 19th century, allowing for stile, and add for the intervening centuries, proceed as before.

EXAMPLES.

Required the sun's longitude and anomaly, July 17, 1860, at 21h. 22m. 9s.

	Longitude.						Anomaly.					
	s	°	′	″	‴	⁗	s	°	′	″	‴	⁗
1860	9	10	34	42			6	0	9	39		
July	5	28	24	8			5	28	23	37		
Days 17	0	16	45	22			0	16	45	19		
Hours 21			51	44	47				51	44	47	
Minutes 22				54	12	38				54	12	38
Seconds 9				0	22	11					22	11
Mean longitude of sun	3	26	36	51	21	49	0	16	11	14	21	49
Equation of sun's centre	–	0	31	36			Anomaly.					
True longitude of sun	3	26	5	15	21	49						

Allowing that Alfred's reign closed Oct. 28, old stile, A. D. 900, what was the sun's longitude and anomaly?

	Longitude.				Anomaly.			
	s	°	′	″	s	°	′	″
1800	9	10	7	13	6	0	44	12
Add for 12 days	0	11	49	40	0	11	49	38
1800, O. S.	9	21	56	53	6	12	33	50
Deduct for nine centuries	0	6	52	14	11	21	21	36
Longitude and anomaly in 900	9	15	4	39	6	21	12	14
October	8	29	4	54	8	29	4	8
Days 28	0	27	35	53	0	27	35	48
Mean longitude and anomaly	7	11	45	26	4	17	52	10
Equation of the sun's centre	–	1	18	48	Anomaly			
True longitude	7	10	26	38				

What was the longitude and anomaly of the sun, March 20, O. S. in the year, that the Children of Israel removed from Egypt, before Christ, 1491 ?

	Longitude.				Anomaly.			
	s	°	′	″	s	°	′	″
1810	9	9	42	14	6	0	8	53
Add for 12 days	0	11	49	40	0	11	49	38
1810, O. S.	9	21	31	54	6	11	58	31
Deduct for 3300	0	25	11	32	10	28	19	12
Commencement of the year B.C.1491,	8	26	20	22	7	13	39	19
March	1	28	9	11	1	23	9	1
Days 20	0	19	42	47	0	19	42	43
Mean longitude and anomaly	11	14	12	20	10	1	31	3
Equation of the sun's centre	+	1	37	30	Anomaly			
True longitude	11	15	49	50				

Required the true longitude and anomaly of the sun, April 12, 1924, at 9h. 42m. 17s. A. M.

	Longitude.						Anomaly.					
	s	°	′	″	‴	⁗	s	°	′	″	‴	⁗
1824	9	10	18	13			6	0	30	23		
Deduct 1 day for stile			59	8	19	47			59	8	9	36
	9	9	19	4	40	13	5	29	31	14	50	24
Add for 1 century	0	0	45	48			11	29	2	24		
Commencement of 1924	9	10	4	52	40	13	5	28	33	38	50	24
April	2	28	42	30			2	28	42	14		
Days 11	0	10	50	32			0	10	50	30		
Hours 21			51	44	47				51	44	47	
Minutes 42			1	43	29	34			1	43	29	34
Seconds 17					41	53					41	53
Mean long. and anomaly	0	20	31	23	38	40	9	8	59	51	48	51
Equation	+	1	53	50			Anomaly.					
True longitude	0	22	25	13	38	40						

This and other examples of the 20th century, may be worked by taking the longitude and anomaly for 1900 with the additional time.

Table X, ought to be made familiar, mistakes being likely to happen without peculiar care.

If the sun's longitude be required for any time at a place east or west of the meridian of Washington, the sun's motion in longitude for the difference in time must be applied. For east, subtract; for west, add. Supqose the sun's longitude be sought at any time for a place 15° east of Washington, find for the time at Washington, and deduct 2′ 27″ 51‴, the motion of the sun for one hour. For a place 15° west, add the hour's motion. Proceed in the same manner for a longer or a shorter time.

TO CALCULATE THE TRUE DISTANCE OF THE SUN FROM THE MOON'S ASCENDING NODE.

This being the argument for the 4th equation in the syzygies, is taken into the examples for ascertaining the true time of new and full moon. The descending node is six signs from the ascending. If the distance at the change or full be less than the ecliptic limit, (see page 96,) an eclipse may be expected. But if the true time of conjunction or opposition be different from the mean, the sun's motion from the node for the difference found in Table X, must be applied.

When the true time is later than the mean time, the motion for the difference must be added; when the true time is earlier than the mean, the motion for the difference must be subtracted. The distance must then be equated by Table XIII.

The true time of new moon, in July 1860, will be 6h. 25m. 39s. later than the mean time.

The sun's mean distance from the node in the example is -	5^s 24° 11′ 42″
Add for 6 hours - - - -	15′ 35″
25m. - - - - -	1′ 4″ 55‴
39s. - - - - - -	1″ 41‴ 16⁗
Mean distance from the node at true new moon, - -	5^s 24° 28′ 23″ 36‴ 16⁗
Equation, - - -	— 0° 34′
True distance of the sun from the ascending node, - -	5^s 23° 54′ 23″ 36‴ 16⁗

SECTION V.

TO PROJECT AN ECLIPSE OF THE SUN.

ELEMENTS NECESSARY.

1. True apparent time of conjunction of the sun and moon.
2. The semi-diameter of the earth's disk, as seen from the moon, equal to the moon's horizontal parallax.
3. Sun's distance from the nearest solstice.
4. Declination of the sun.
5. Angle of the moon's path with the ecliptic.
6. Latitude of the moon.
7. Horary motion of the moon from the sun.
8. Semi-diameter of the sun.
9. Semi-diameter of the moon.
10. Semi-diameter of the penumbra.

To find these elements for an eclipse; and as an example, for the eclipse in July, 1860, at Boston.

1. The true apparent time of conjunction of the sun and moon for Boston at that time, is found by the example in page 118, to be 17d. 21h. 39m. 46s. viz. in civil time, 18d. 9h. 39m. 46s. A. M.

2. To find the moon's horizontal parallax.

With the moon's anomaly as an argument enter table XV, and making proportions, the table being formed to every sixth degree only, find the horizontal parallax of the moon. This at the time of the eclipse in July, 1860, will be 59′ 24″.

3. To find the sun's distance from the nearest solstice.

The summer solstice is 3 signs; the winter 9 signs from the 1° of Aries. To find the sun's distance from either, at any time, find his longitude in table X, and by that, his distance from the solstice to which he is nearest. When the longitude is less than 3 signs, or more than 6 and less than 9, subtract the longitude from the solstice. When the longitude is more than three signs, and less than 6, or more than 9, subtract the solstice from the longitude. The sun's true longitude at the time of the eclipse in July, 1860, is found to be $3^s\ 26° 5' 15''$. From this if 3^s be subtracted, the remainder is 26° 5′ 15″, which is the sun's distance from the summer solstice.

4 To find the declination of the sun.

With his true longitude, found in table X, as an argument, find his declination in table XII. This at the time of the eclipse to be calculated will be 20° 57′ 20″.

5. To find the angle of the moon's path with the ecliptic.

With the anomalies of the sun and moon, find their respective horary motions in table XV. Subtract the horary motion of the sun from that of the moon. Seek and note the difference in table XVII. Take the signs and degrees of the sun's true distance from the node as an argument. Against the degrees and under the difference of horary motion will be the angle of the moon's path with the ecliptic. This at the time of the eclipse to be projected will be 5° 39′.*

6. To find the latitude of the moon.

With the argument, the moon's equated distance from the node, equal to the sun's, find this in table XIV. This at the eclipse will be 31′ 55″.

7. To find the horary motion of the moon from the sun.

With the anomalies of each separately, find their horary motions in table XV, as before directed. Subtract the sun's from that of the moon. The difference is the horary motion of the moon from the sun. This at the eclipse will be 33′ 25″.

8. To find the semi-diameter of the sun.

With the argument, the anomaly of the sun, find his semi-diameter in table XV. At the eclipse this will be 15′ 51″.

9. To find the semi-diameter of the moon.

With her anomaly, her semi-diameter is found in table XV. For the eclipse this will be 16′ 15″.

10. To find the semi-diameter of the penumbra.

Add together the semi-diameters of the sun and moon, the

* Mr. Ferguson says that 5° 35′ may be always rated as the angle of the moon's path with the ecliptic, without any sensible error.

sum is the semi-diameter of the penumbra. For the eclipse 15′ 51″ + 16′ 15″ = 32′ 6″.

These elements collected, as they always should be for convenient use, are;

1. Apparent time of new moon in July, 1860,	18d. 9h. 39m. 46s. A. M.
2. The moon's horizontal parallax,	59′ 24″
3. Distance of the sun from the summer solstice,	26° 5′ 15″
4. Declination of the sun,	20° 57′ 20″
5. Angle of the moon's path with the ecliptic,	5° 39′
6. Latitude of the moon, north descending,	31′ 55″
7. Horary motion of the moon from the sun,	33′ 25″
8. Semi-diameter of the sun,	15′ 51″
9. Semi-diameter of the moon,	16′ 15″
10. Semi-diameter of the penumbra,	32′ 6″

TO PROJECT THIS ECLIPSE GEOMETRICALLY.

From an accurate diagonal scale, or a scale made for the purpose of any convenient length, take as many parts, as the moon's horizontal parallax contains minutes of a degree.—With this distance as a radius describe the semi-circle *A M B*, (*Plate IX. Fig.* 1.*) Upon the centre, *C*, raise the perpendicular *C D*. Then will *A C B* represent a part of the ecliptic; *C D* its axis; and *D* will bisect the semi-circle into two equal parts, each a quadrant † Divide one of these, as *B D*, into 9 equal parts, and subdivide into degrees, making the quadrant 90°. Take the chord of 23½ of these in your dividers, and set from *D* each way to *E* and *F*, and draw the line *E H F*. With *H E* or *H F*, as a radius, and one foot of the dividers in *H*, describe the semi-circle *E G F*, extend the line *C D* to *G*. Divide the quadrant *E G* into 9 equal parts, the earth's axis being on the left hand, and subdivide it into degrees. When the sun is in Aries, Taurus,

* The plane scale on the opposite side of Gunter, when very accurate, may be used, in taking the parts for this sweep, or the semi circle may be first drawn, and the radius divided into a number of parts equal to the moon's horizontal parallax. Great accuracy in the scale is of first importance.

† A sector is convenient for projecting eclipses. This however being in the hands of but few, it was thought proper to show the operation by the much more common instruments, the scale and dividers. Those acquainted with the sector will easily apply its use.

Gemini, or Capricornus, Aquarius, Pisces, the northern half of the earth's axis is on the right hand of the axis of the ecliptic; when the sun is in the other six signs, it is on the left; or, from the winter to the summer solstice, it is on the right hand; from the summer to the winter solstice it is on the left. Take the sine of the sun's distance from the solstice, 26° 5′ 15″, guessing at the minutes and seconds, as the line *g h*, and set it from *H* to *P* on the line *E H*. *P* will represent the north pole of the earth, on the 18th of July, 1860.—Draw the line *C P* for the semi-axis of the earth.

Subtract the sun's declination from the latitude of the place, the sine of the remainder taken from the graduated quadrant *B D*, and set upon the axis *C P*, will be the distance of the place from the ecliptic on the noon of the day, when the eclipse happens; thus 42° 23′ — 20° 57′ 20″ = 21° 25′ 40″. The sine of this is the line *a b*, which on the line *C P* will extend from *C* to *i*. Add the declination to the latitude, the sum taken as a sine, *c d*, from the same graduated quadrant, *B D*, and set on the axis *C P*, or on the same produced if necessary beyond *P*, will extend from *C* to the position of the place at midnight of the same day, 42° 23′ + 20° 57′ 20″ = 63° 20′ 20″ will extend from *C* to *j* on the axis: *j* is the point passed by Boston at midnight of July 18th, 1860. Bisect *i j* at *k*. Take the co-sine of the latitude of the place from the quadrant *B D*; 90° — 42° 23′ = 47° 37′, = *e f* and set each way from *k* to *VI* and *VI*, connecting these with a straight line perpendicular to *C P*. *VI* and *VI* will be in the margin of the disk at the equinoxes, but at no other time.—With the distance *k VI* draw the semi-circle *VI* 12 *VI*. Divide each quadrant into six equal parts, and mark it 7, 8, 9, 10, 11, 12, 1, 2, 3, 4, 5, as in the diagram. From the points of division draw lines parallel to the axis *C P* to the line *VI k VI* for hour lines. The semi-circle should be sub-divided into quarters or minutes, and lines drawn parallel to the hour lines. These are best done with the foot of the dividers, and may, or may not, be dotted as in the example. With the exent *k i* draw the quadrant *i l*. Lay a ruler from *k* to the several divisions on the external quadrant, 12 *VI*, and where it cuts the quadrant *i l* mark, and thus divide it into six equal parts. Or it may be divided by stepping the dividers. Through the points of division in the small quadrant, draw lines parallel to the line *VI k VI*, till they intersect the hour lines on each side of the axis. Through the points, where these lines meet the hour lines, 6, 7, &c. from *VI*, on one side to *VI*, on the other, draw with a pen or pencil an elliptic curve. This will represent the path of the place over the earth's disk, as seen from the moon on the day of the eclipse. When the sun is in south declination, the elliptic curve, representing the path of the place, must be drawn on the upper side of the line *VI k VI*. The order must be reversed in drawing for places in the south latitude.

The ellipse representing the path of the place on the earth's disk may be more easily, and perhaps more elegantly delineated by considering *VI k VI* as the transverse, and *i j* as the conjugate. The mean proportional between the sum and difference of these is the distance of the foci. At the place of the hours, however, unless drawn with great attention, it might not be so accurate, as the method used in the diagram. Set the degrees and minutes in the angle of the moon's path with the ecliptic, 5° 39′, from *D* to *M*, her latitude being north descending. Draw the line *C M* for the axis of the moon's orbit. When the moon's latitude is north or south ascending, the axis of her orbit must be represented on the left hand of the axis of the ecliptic; but when her latitude is north or south descending, the axis of her orbit must be on the right hand of the axis of the ecliptic. Bisect the angle *D C M* by the line *C m*. Take the moon's latitude 31′ 55″ from your scale, and set it from the line *A C B* to *n* on the bisecting line *C m*, as the line *n o* parallel to *C D*.— Through *n* at right angles to the axis *G M* draw *N O* for the path of the moon's shadow over the earth at the time of the eclipse.

Take from your scale the moon's horary motion from the sun 33′ 25″, and making it equal to *Q R*, (*Plate IX. Fig. 2.*)

divide it into 60 equal parts for minutes; or it may be divided into larger parts of two, three, five, or ten minutes each, at pleasure. Set the true time of new moon on the line *N O* at *n*, where it intersect the line *C m*. Then from *Q R*, the line of horary motion, take the minutes and seconds passed after the hour preceding the conjunction, and set them from *n*, backwards on the path of the shadow towards *N*. Thus 39m. 46s. will extend from *n* to *IX.* on that path. Take the whole extent of *Q R*, and set it each way from *IX*, to the different hour marks as on the line *N O*. The marks will show the centre of the moon's shadow at the times specified. The spaces may be subdivided into quarters, five minutes, or minutes, as may be convenient.

Apply the side of a square to the path of the moon's shadow, and, as you move it along, observe, when the other side cuts the same time in that path and in the path of the place over the earth's disk. This time is the instant of greatest obscuration. From the scale take the sun's semi-diameter, and setting one foot of the dividers in the path of the place at the point of greatest obscuration, draw a circle to represent the sun, as seen at the centre of the eclipse. With the moon's semi-diameter, taken from the scale, as a radius, make a circle on the path of her shadow, the centre at the point, where the centre of her shadow is at the greatest obscuration, representing her disk at the same time. The circle of the moon being shaded with ink or paint, the appearance of the sun at the centre of the eclipse will be represented. The part only of the sun covered by the moon may be shaded, if preferred.

From the scale take the semi-diameter of the penumbra, and setting one foot of the dividers backwards, on the path of the shadow, *N O*, the other on the path of the place, observe when each is at the same instant. Note this is as the beginning of the eclipse. With the dividers at the same extent, and one foot in each path, after the greatest obscuration, note the point, where each is at the same instant by the marks, as the end of the eclipse. Thus we find that the eclipse of July 18th, 1860, at Boston, beginning at 7h. 22m. middle 8h. 28m. end 9h. 37m. A. M.

With a ruler laid over the centres of the sun and moon, as represented, draw the diameter of the sun's disk, and divide it into 12 equal parts. The number of these within the moon's disk, are the digits eclipsed.

Most of this operation supposes the projector to stand at the moon, or in the ecliptic opposite, looking down upon the earth. To find the duration of complete darkness in a total eclipse of the sun, subtract the apparent semi-diameter of the sun from that of the moon, take in the dividers the minutes of the difference from the scale, making allowance for seconds; place one foot of the dividers in the path of the moon's shadow, the other in the path of the place, and proceed in the same manner in finding the beginning and end of total darkness, as in finding the beginning and end of the eclipse by the semi-diameter of the penumbra.

Alexander A. Fish Penryn

SECTION VI.

PROJECTION OF LUNAR ECLIPSES.

By page 96, we find, that when the moon is within about 11° of either of her nodes, she may be eclipsed.

The elements for projecting a lunar eclipse are 8.

1. The true time of full moon.
2. The moon's horizontal parallax.
3. The sun's semi-diameter.
4. The moon's semi-diameter.
5. The semi-diameter of the earth's shadow at the moon.
6. The moon's latitude.
7. The angle of the moon's visible path with the ecliptic.
8. The moon's horary motion from the sun.

1. To find the true time of full moon, see preceding directions, page 117.

All the other elements for projecting a lunar eclipse, may be found by the directions for the same in solar eclipses, except the fifth.

To find the semi-diameter of the earth's shadow at the moon, add the horizontal parallax of the moon to that of the sun; from the sum subtract the apparent semi-diameter of the sun.

The eclipse of the moon in November, 1808, as seen at the Capitol, is represented in the following delineation, for an example of lunar projection. (*Plate VIII. Fig.* 1.) The student, who acquaints himself with the course of the moon, and with the tables, will be able to vary the position of the axis, so as to project other eclipses of the moon from this example. The axis of the moon's orbit is usually placed as in solar eclipses, and when the moon is in south latitude, her course is marked from the right to the left, considering the upper part of the plate north. The representation, however, would correspond better to the real appearance, if, when the moon is south descending, the axis of her orbit be laid on the left hand, when she is south ascending, on the right; and her path marked from the left to the right.

At the time of full moon, in November, 1808, the sun's anomaly was $4^s\ 3°\ 3'\ 6''$; the moon's, $11^s\ 27°\ 21'\ 51''$; the sun's equated distance from the moon's ascending node $11^s\ 28°\ 25'\ 53''$. To this, if 6 signs be added, it gives the moon's place $5^s\ 28°\ 25'\ 53''$, bringing her within $1°\ 34'\ 7''$ of her descending node.

ELEMENTS.

1. True apparent time of full moon, - - - - -	3d. 3h. 22m. 5s.			
2. The moon's horizontal parallax, - - - -		54′	30″	
3. The sun's semi-diameter, - - - - -		16′	15″	
4. The moon's semi-diameter, - - - - -		14′	54″	
5. The semi-diameter of the earth's shadow at the moon,		38′	24″	
6. The moon's latitude, - - - - - -		8′	14″	north des.
7. The angle of the moon's visible path, - - -	5°	45′		
8. The moon's horary motion from the sun, - - -		27′	40″	

Draw the line *A C B* at random, (*Plate VIII. Fig.* 1.) From a diagonal scale, or a scale made for the purpose, take as many parts, as the moon's semi-diameter added to the semi-diameter of the earth's shadow, at the moon, contains minutes of a degree, 14′ 54″ + 38′ 24″ = 53′ 18″. With this extent draw the semi-circle, *A D B*, above the line *A C B*, the moon's latitude being north. For south latitude, the semi-circle must be drawn on the other side. When it may be necessary for representing the whole eclipse, a segment greater than a semi-circle may be drawn, and the figure extended, as in the diagram to *I K* and *i k*. Divide one quadrant of this into degrees. Take *D M*, 5° 45′, the angle of the moon's visible path, and draw the line *C M* for the axis of the moon's orbit, on the right hand, the latitude of the moon being north descending. With the semi-diameter of the earth's shadow at the moon, 38′ 24″, from the centre *C* draw the semi-circle *c d e*, for the northern half of that shadow. Bisect *D M* in *a*, and draw the occult line, *C a*. Set the moon's latitude, 8′ 14″, perpendicularly from the line *A C B* to *b* on the line *C a*. Through *b* and perpendicular to the axis *C M*, draw the line *E F* for the path of the moon through the earth's shadow. Make the line *G H*, *Fig.* 2, equal to the horary motion of the moon from the sun, and divide it into 60 equal parts for minutes. Or it may be divided into larger parts of 3, 5, or 10 minutes each. Place the true time of full moon at *b* where the line *E F* intersects the line *C a*; and set 22 minutes, taken from the line, *G H*, backward on the line *E F* from *b* to III. With the whole line, *G H*, mark the line, *E F*, each way from III. The dots at I, II, III, IV, V, show the moon's place at those hours. The spaces between the hour marks may be divided into minutes, or five minutes, as may be thought requisite.

With the semi-diameter of the moon as a radius, draw circles at *f*, *g*, and *h*.—*f* will represent the moon's place at the beginning, *g* at the middle, and *h* at the end of the eclipse.

The disk of the moon, like that of the sun, may be divided into 12 equal parts for digits, and the amount of the eclipse ascertained. Where great accuracy is required, each digit may be divided into 60 equal parts for minutes.

Plate IX, *Fig.* 3 and 4, are projections of the lunar eclipse, as seen at the Capitol, January 16, 1824. It will appear, that the result is the same, in the different positions, in which the axis of the moon's orbit is placed. Figure 3 is delineated in the manner common in such projection. But, without doubt, figure 4 best represents the true appearance.

CHAPTER VIII.

DIVISIONS OF TIME.

Time, as measured by the heavenly bodies, is divided into periods, cycles, years, months, weeks, days, hours, minutes, and seconds. Thirds, fourths, fifths, or any sexagesimal may be taken.

Periods, astronomically considered, are large divisions of time. The Chaldean period, is a circle of 25,858 years, at the termination of which the poles of the earth will be directed to the same stars, as at the beginning.

The Julian period is a round of 7980 years, found by multiplying together the cycles, 28, 19, and 15. Its commencement depended on the commencement of the cycles of which it is composed. The creation of the world was on the 706th year of the Julian period. The Dionysian era of Christ's birth was near the end of the 4713th year of this period.—The Julian period, though imaginary, is very useful in comparing the dates of ancient events.

The Dionysian period, or circle of Easter, is formed by multiplying the solar cycle 28, into the lunar 19.

CYCLES ARE REVOLUTIONS OF TIME.

The Cycle of the sun is a period of 28 years. This cycle brings the days of the week to the same days of the month; the sun to the same signs and degrees of the ecliptic with little variation in each succeeding period. The leap years also have a regular rotation in this cycle. Each of these events has separately a much shorter period. But the cycle brings them to coincide.

The Cycle of the moon, or Golden number, is a circle of 19 years, at the expiration of which, the changes, fulls, and other aspects of the moon, return to the same month and day of the month, or within a day of the same time, as at the beginning.

The Epact is the excess of the solar above the lunar year of 12 mean lunations, or 354 days. It is the age of the moon on the first day of January.

The Roman Indiction is a period of 15 years. It was established by Constantine in the year 312, for indicating the times of certain payments made by the subjects to the government.

To find the Cycle of the sun, Golden number, and Indiction, add to the year of the Christian era 4713, and divide the sum by 28, 19, and 15, respectively ; the remainders are the numbers for the year.

Suppose these numbers required for the year 1825.

1825	28)6538(233	19)6538(344	15)6538(435
+4713	56	57	60
——	—	—	—
6538	93	83	53
	84	76	45
	—	—	—
	98	78	88
	84	76	75
	—	—	—
	14 Cycle of the Sun.	2 Golden number.	13 Indiction.

To find the Julian Epact, multiply the Golden number of the year by 11, the product, if less than thirty, is the Epact. If the product exceed thirty, divide it by 30, the remainder is the Epact.

To find the Gregorian Epact, find the Julian Epact, and subtract the difference between the old and new style, 12 days for the present century, the remainder is the Gregorian Epact.* If nothing remain, 29 is the Epact. If the subtraction cannot be made, add 30 to the Julian Epact, and subtract as before.

Neither the Golden number nor the Epact can be of much use, where accuracy is required. The Roman Indiction is still less important.

A year is a complete revolution of the seasons. The difference between the tropical, sidereal, and anomalistic year, has been before considered.

Different nations have had different methods of computing their year. The civil solar year, as used by the United States and European nations, consists of 365 days, and in bissextile, 366.

The lunar year consists of 354 days, or 12 lunar months. In this calendar every third year is intercalary or Embolimic, a month being added to make the lunar coincide with the solar year. The Jews kept their accounts by lunar years. "But by intercalating no more than a month of thirty days, which they called Ve-Adar, every third year, they fell 3¾ days short of the solar year in that time."

The year of the Greeks was composed of 12 months of 29 and 30 days alternately, comprising very nearly 12 lunations, or 354 days. It was difficult to connect this lunar year, with the revolutions of the sun, so as to make the several months fall in the same seasons in successive years. "The Olympic games were celebrated every fourth year during the full moon next after the summer solstice ; and the year of the Greeks was so regulated as to make this the full moon of the first month. This purpose was effected by intercalations ; but these were managed so injudiciously, that in the time of Meton the calendar and the celebration of the festivals had fallen into great confusion."

* The ingenious student will perceive, that the rule of Mr. Pike and some others, to deduct 11 for the difference of the Epacts, applies to the last century only.

The ancient Romans reckoned by the Lustrum, a period of 4 years. They also computed by lunar years, as established by Romulus, till Julius Cæsar reformed the calendar and introduced the system of computation, which has borne his name to the present time. In this computation, three years were common, consisting of 365 days, as in the present calendar. Every fourth year had 366 days, the 24th of February being twice reckoned. This being the 6th of the calends of March was called *bis sextus dies*, bissextile. The additional day is now placed at the last of February, and from it the year is called bissextile.

The Julian calendar continued for a long time in Europe. But, it having been found by observations on the time of Easter, that the civil year was too long for the tropical, another attempt was made to reform the calendar.

At the time of the council of Nice, 325 of the Christian era, the vernal equinox fell on the 21st of March. In 1582, Pope Gregory XIII, observing that the same equinox happened 10 days earlier in the year than it had done at the time of the Nicene council, altered the calendar 10 days, ordering, that the 5th of October should be called the 15th. The style thus altered was called the Gregorian, or new style. Though adopted and used in several countries of Europe, it was not received into England till the year 1752. The old style or Julian calendar still prevails in Russia. The difference between the old style and the new in the present century is 12 days.

Pope Gregory not only altered the style; but endeavoured to establish a principle, by which the civil, or political year, would coincide with the tropical. By this principle bissextile is to be omitted three times in 400 years. When the centuries of the Christian era are divided by 4, if nothing remain, the leap year is to be retained. But if there be a remainder, the year is to be reckoned common. Thus at the end of the 19th century, the leap year is to be omitted, there a being remainder, when 19 is divided by 4.

The omission of three bissextiles in 400 years, still leaves the civil year 20 seconds, 24 thirds longer than the tropical year, as computed by La Place. This excess will amount to a day in 4235 years. The omission of one bissextile in 129 years would bring the different computations to great nearness.

The principal division of the year is into *months.* These are lunar, solar and civil. The sidereal lunar month is the time the moon is passing from the star to the same again ; as before explained. But the principal lunar months consist of a lunation, or the time of the moon's passing from change to change. This seems to have been the foundation of *months*, and to have given the name to this division of time. The solar month is the time the sun is passing one of the signs, or the 12th part of a year.

The civil month is of two kinds. That called the weekly month consists of 4 weeks, and is always equally long. This is the true legal month. "A month in law" says Blackstone, "is a lunar month, or twenty-eight days, unless otherwise expressed ; not only because it is one uniform period, but because it falls naturally into a quarterly division by weeks. Therefore a lease for "twelve months" is only for forty-eight weeks ; but if it be for "a twelvemonth" in the singular number, it is good for the whole year."

The months in our calendar are of Roman origin. The Latin names are retained, some of them assuming an English termination. Till the time of Augustus Cæsar, the sixth month was called Sextilis. In honour of that emperor it was changed to Augustus. To heighten the compliment, a day was taken from the last of February and added to August.—Before that time August consisted of but 30 days ; February in a common year of 29.*

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* The number of days in each month is conveniently remembered by the following lines:

"Thirty days hath September,
April, June and November,
All the rest have thirty one,
Saving February alone."

A week, a well known portion of time, consists of 7 days. This division, old as creation, undoubtedly had its origin in the resting of Jehovah from his work, and the establishment of the sabbath.

Days are artificial or natural. An artificial day is the time the sun is above the horizon. A natural day is the space of 24 hours ; or the time, in which any meridian on the earth moves from the sun to the sun again. The ancient Egyptians began their day at midnight. Most European nations, and the United States, begin at the same time. This is our civil day, divided into two twelves. The ancient Jews began their day at sun setting. They divided the night and the day, each into 12 equal parts, at all seasons of the year. These must therefore, have been of unequal length ; though not so unequal, as in such a division with us, Palestine being nearer the equator than the United States. The ancient Greeks also, began their day at sunsetting, a practice followed by the Bohemians, Silesians, Italians and Chinese.—The Babylonians, Persians, and Syrians, commenced their day at sunrising. This is the practice of the modern Greeks.

The nautical, or sea day, commences at noon, 12 hours before the civil day. The first 12 hours are marked P. M. the last A. M. The astronomical day begins at noon, 12 hours after the civil day, and is reckoned numerically from 1 to 24.

An hour is the 24th part of a natural day, as measured by a good clock or watch. The division of the day into hours is very ancient. "Herodotus observes, that the Greeks learned from the Egyptians, among other things, the method of dividing the day into 12 parts. The division of the day into 24 hours was not known to the Romans before the Punic war. Till that time they only regulated their days by the rising and setting of the sun." They divided the day into four watches commencing at 6, 9, 12, and 3 o'clock. The night also, they divided into four watches of three hours each.

An hour is divided into 60 minutes; a minute into 60 seconds; a second into 60 thirds. Farther subdivisions are sometimes made, as fourths and fifths, in sexagesimal order.

The first seven letters of the alphabet were formerly set in almanacks for the days of the week. They were introduced by the primitive Christians, instead of the nundinal letters in the Roman calendar. As one of these must stand for the sabbath, it was written in capitals, and called the dominical letter, from Dominus, the Latin word for Lord.—The dominical letter is still retained in almanacks; but figures are substituted for the other letters.

If a common Julian year, 365 days, be divided by 7, the number of days in a week, 1 will remain. Where there is no remainder, and no bissextile, each succeeding year would begin on the same day of the week. But, one remaining, the year will begin and end on the same day of the week. When January begins on Sunday, *A* is the dominical letter for that year. But the next year commencing on Monday, *a*, or the substituted figure, is set to that day, as it is always placed at the first day of January. *G* will, therefore, be the dominical letter for that year, the Lord's day being the seventh of the month. As the following year must commence on Tuesday, *F* is the dominical letter for that year. Thus the letters would follow in retrograde order throughout the seven, *G, F, E, D, C, B, A;* and at the end of seven years, the days of the week would return to the same days of the month, as before. But there being 366 days in bissextile, if this be divided by 7, 2 will remain, thus interrupting the regular returns.

The order of placing the letters was to put *A* at the first day of January, *B* at the second, *C* at the third, and so on through the seven; and then repeat the same successively through the year. The same letters, therefore, stood at the same days of each month, in every succeeding year. That this order might not be interrupted by leap year, *C*, always at the 28th of February, was placed at the 29th also, or, according to some tables, *D* was repeated. Thus the succeeding months began with the same letters in bissextile, as in common years. But two letters became dominical.—Suppose *D* the dominical letter for a year, *C*, at the 28th of February, must represent Saturday, *C* also, must be at the 29th, if the year be bissextile, and of course become dominical; or, if D be doubled, *C* at the 7th of March, becomes dominical, and so remains through the year. The next year begins two days later in the week. On this account the seven letters, in their retrograde revolution, occupy 5 years, when leap year is twice included; 6, when it is once included. Hence the days of the week return to the same days of the month in 5 or 6 years, according as bissextile is twice, or but once included. The letters will always have 5 revolutions in 28 years; except, when leap year is omitted, at the end of a century.

The following table shows the dominical letter for 6000 years of the Christian era, according to the Gregorian calendar.

A TABLE OF DOMINICAL LETTERS FOR 6000 YEARS OF THE CHRISTIAN ERA, N. S.

				1 0 0 5 0 0 9 0 0 1 3 0 0 1 7 0 0 2 1 0 0 2 5 0 0 2 9 0 0 3 3 0 0 3 7 0 0 4 1 0 0 4 5 0 0 4 9 0 0 5 3 0 0 5 7 0 0	2 0 0 6 0 0 1 0 0 0 1 4 0 0 1 8 0 0 2 2 0 0 2 6 0 0 3 0 0 0 3 4 0 0 3 8 0 0 4 2 0 0 4 6 0 0 5 0 0 0 5 4 0 0 5 8 0 0	3 0 0 7 0 0 1 1 0 0 1 5 0 0 1 9 0 0 2 3 0 0 2 7 0 0 3 1 0 0 3 5 0 0 3 9 0 0 4 3 0 0 4 7 0 0 5 1 0 0 5 5 0 0 5 9 0 0	4 0 0 8 0 0 1 2 0 0 1 6 0 0 2 0 0 0 2 4 0 0 2 8 0 0 3 2 0 0 3 6 0 0 4 0 0 0 4 4 0 0 4 8 0 0 5 2 0 0 5 6 0 0 6 0 0 0
Yrs less than 100				C	E	G	B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	E D	F E
9	37	65	93	F	A	C	D
10	38	66	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

The dominical letter for any of the years less than 100 is found in the column of letters next to those years, opposite to the year for which it is sought. For any year above 100, find the century at the top; in the column beneath, opposite to the year of the century, in the column less than 100, is the dominical letter sought.

EXAMPLE.

Under 1800, opposite to 25 in the left hand column, is B, the dominical letter for 1825.

Knowing the dominical letter, it will be easy to find the day of the week, on which any month begins, by the subjoined table.

A	B	C	D	E	F	G
Jan.	May	Aug.	Feb.	June	Sept.	April
Oct.			March		Dec.	July.
			Nov.			

A TABLE showing the days of the months by dominical letters.

D. Letters.	A	B	C	D	E	F	G
	1	2	3	4	5	6	7
January 31	8	9	10	11	12	13	14
October 31	15	16	17	18	19	20	21
	22	23	24	25	26	27	28
	29	30	31	—	—	—	—
	—	—	—	1	2	3	4
Feb. 28–29	5	6	7	8	9	10	11
March 31	12	13	14	15	16	17	18
Nov. 30	19	20	21	22	23	24	25
	26	27	28	29	30	31	—
	—	—	—	—	—	—	1
	2	3	4	5	6	7	8
April 30	9	10	11	12	13	14	15
July 31	16	17	18	19	20	21	22
	23	24	25	26	27	28	29
	30	31	—	—	—	—	—
	—	—	1	2	3	4	5
	6	7	8	9	10	11	12
Aug. 31	13	14	15	16	17	18	19
	20	21	22	23	24	25	26
	27	28	29	30	31	—	—
	—	—	—	—	—	1	2
	3	4	5	6	7	8	9
Sept. 30	10	11	12	13	14	15	16
Dec. 31	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
	31	—	—	—	—	—	—
	—	1	2	3	4	5	6
	7	8	9	10	11	12	13
May 31	14	15	16	17	18	19	20
	21	22	23	24	25	26	27
	28	29	30	31	—	—	—
	—	—	—	—	1	2	3
	4	5	6	7	8	9	10
June 30	11	12	13	14	15	16	17
	18	19	20	21	22	23	24
	25	26	27	28	29	30	

To assist the memory, the following couplet is inserted, somewhat appropriate, substituted for the hacknied, unmeaning one, in common use.

All days decline; great blessings end;
Good Christians find a during friend.

The first letters of these twelve words are the same as those at the beginning of each month.

As much as the letter set at the first day of a month is before, or after the dominical letter in the year, sought, so much is the day, on which the month begins, before or after the Lord's day. Thus, if *A* be the dominical letter, January begins on Sunday, February and March on Wednesday. If *B* be the dominical letter, January begins on Saturday, February and March on Tuesday.

CHAPTER IX.

OBLIQUITY OF THE ECLIPTIC.

"The obliquity of the ecliptic to the equator," says Dr. Brewster, "was long considered as a constant quantity.—Even so late as the end of the 17th century, the difference between the obliquity, as determined by ancient and modern astronomers, was generally attributed to inaccuracy of observation, and a want of knowledge of the parallaxes and refraction of the heavenly bodies. It appears, however, from the most accurate modern observations, at great intervals, that the obliquity of the ecliptic is diminishing.

By comparing about 160 observations of the ecliptic, made by ancient and modern observers, with the obliquity of 23° 28′ 16″, as observed by Tobias Mayer, in 1756, we have found, that the diminution of the obliquity of the ecliptic, during a century, is 51″; a result which accords wonderfully with the best observations." This would bring the obliquity at the present time, 1825, to 23° 27′ 41″.

Professor Vince, after stating the observations of many authors, ancient and modern, concludes, "It is manifest, from these observations, that the obliquity of the ecliptic, continually decreases; and the irregularity which here appears in the diminution we may ascribe to the inaccuracy of the observations, as we know that they are subject to greater errors, than the irregularity of this variation."

The following table, extracted from Rees' Cyclopædia, will give an idea of the diminution of the obliquity.

Obliquity of the ecliptic from observations at different times.					Mean obliquity for forty centuries.			
	A. C.	°	′	″	B. C.	°	′	″
Pytheas,	324	23	49	23	900	23	50	26
Eratosthenes,	230	23	51	20	400	23	46	30
Hipparchus,	140	23	51	20	0	23	43	15
	A. D.				A. D.			
Ptolemy,	140	23	48	45	100	23	42	26
Arzachel,	1104	23	33	30	500	23	39	6
Propatius,	1300	23	32		1000	23	34	51
Waltherus,	1476	23	30		1500	23	30	33
Tycho Brahe,	1584	23	31	30	1700	23	28	49
Kepler,	1627	23	30	30	1800	23	27	57
Flamstead,	1690	23	29		2000	23	26	12
Mayer,	1756	23	28	16	2500	23	21	51
Maskelyne,	1800	23	27	56,6	3000	23	17	31

The part of the table on the left, taken from actual observations, ancient and modern, will be found nearly to coincide with that on the right, formed, by calculation from the most accurate modern observations.

The attraction of the moon, on the spheroidical figure of the earth, affords so natural an explanation of the cause of diminution, in the obliquity of the ecliptic, that it is wonderful any other should have been sought.

Let *T*, (*Plate VIII. Fig.* 5.) be the earth, *M* the moon, *N S* the earth's axis, *E Q* the equator; the line *T M* a radius of the moon's orbit at a node, or where it coincides with the plane of the ecliptic; *A B* the diameter of the earth, as cut by the plane of the ecliptic. In the triangle *A M Q*, the line, *M Q* may represent the force of the moon's attraction on the accumulated matter of the earth, at the equator, on the side next to the moon. This force by the principles of motion, may be resolved into two other forces,* represented by the lines *A M* and *A Q*; the former of which being in the plane of the ecliptic, cannot affect the inclination; but the latter operates to diminish the obliquity.— This force must act in every part of the moon's orbit, except at the beginning of Aries and Libra.

* Enfield, Mechanics, Book II, Chapter III, Prop. XVI.

The action of the moon on the opposite side of the earth, must be counter to that we have considered. But, from the well known principle, that the force of gravity diminishes as the squares of the distances increase, the effect on different sides of the earth must be unequal, and least on that side, which is opposite to the moon. But if the force of the moon's attraction on the different sides of the earth were equal, the counter action on the opposite side must be less than the diminishing action on the side of the earth next to the moon; for the line *B E* is equal to *A Q*; but the line *BM* is longer than *A M*. If therefore *B E* and *B M* represent a force equal to *A Q* and *A M*, as in the hypothesis, *B E* must be less in proportion to the whole than *A Q*; *B E* being less in proportion to *B M* than *A Q* is to *A M*. Unequals being taken from equals, the remainders are unequal.

The inclination of the moon's orbit to the plane of the ecliptic must cause her action to be greater at some times than at others; but cannot prevent her operating in every revolution to diminish the obliquity.

The attraction of the sun on the matter accumulated at the earth's equator must produce an effect similar in kind to that of the moon. But the distance of the sun from the earth is so great, that the line *A Q* bears a very small proportion to the line *Q M* or *A M*. The attraction of the sun also, in different parts of the earth, becomes almost equal, as in the case of the tides. The effect of the other planets on the obliquity must be extremely small.

If the explanation here given of the cause of the diminution in the obliquity be just, it can neither become stationary nor increase without power extrinsic to the solar system; but must continually decrease, and in time become extinct.—Should the earth continue to such an event, the variety of seasons must cease. But to produce such an event, at the present ratio of decrease, would require about 165,000 years from the present time; a period too immense for our comprehension. He, who formed the earth by a word, can destroy it at pleasure, or renovate it, so as to produce "seed time and harvest, and summer and winter."

CHAPTER X.

SECTION I.—PARALLAX.

Parallax, as before defined, is the difference between the true and apparent place of a heavenly body. The *true* place of a body is where it would appear if seen from the centre of the earth; *apparent*, where seen from its surface. Parallax is largest at the horizon and decreases to the zenith, where it is nothing.

Let *A B D* (*Plate VII. Fig.* 10,) be the earth, *C* its centre; *M N O P*, the moon in different altitudes. When the moon is at *M*, she would be seen from the earth's centre among the stars at *E*; but as seen from *A*, the surface, she appears at *F*. When at *N*, she would be seen from the centre at *G*; but from *A* she seems at *H*. At *O*, her parallax is lessened, as from the different stations, she would be seen at *I* and *K*. At *P*, having no parallax, she appears at the same place, being seen at *Z*, both from *C* and *A*.

This parallax decreases with the distance (*Plate VII. Fig.* 10,) of the body from the earth, being inversely as the distance.* It is often called *diurnal* parallax.

Annual parallax is the difference in the apparent place of a heavenly body, as seen from opposite points in the earth's orbit. This orbit is about 190 millions of miles in diameter.

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* This is manifest from a view of the figure. It is however capable of demonstration; for the angle *A M C* is equal to the angle *M C V*+*M V C*, as in Plate VII, Fig. 6. But the sum of these angles is greater than the angle *M V C*, the whole being greater than a part; the angle *A M C* is therefore greater than the angle *M V C*.

Hence an object, unless immensely distant, as seen from one part, must appear in a very different place in the heavens, from the same object as seen from the opposite part.

SECTION II.

PARALLAX OF THE MOON.

The diurnal parallax of the moon has been long known. It may be obtained from one observation, when she passes the meridian of a place, if the latitude of the place and the moon's declination be accurately ascertained. The latitude of many places is well known; of any, may be known. The declination of the moon may be calculated for any time. It may be obtained with accuracy in an eclipse, central, or nearly central, at the meridian over which the moon passes at the middle of such eclipse.

Let *A B D* be a meridian of the earth (*Plate VII, Fig.* 11.) *C*, its centre; *M*, the moon. The angle at *C* may be found by adding the declination of the moon to the latitude of the place, or subtracting it from that latitude, as the case may require; the angle *C A M* is obtained by subtracting the zenith distance of the moon, found by observation, from 180°. Then these two angles *C A M*+*A C M* taken from 180° leave the angle *A M C*, the moon's parallax. To find the side *C M*, the distance of the moon, the side *A C* is given, being the semi-diameter of the earth, and all the angles.—By trigonometry, as the sine of the angle *A M C* is to the side *A C*; so is the sine of the angle *C A M*, to the side C *M*.

In taking the altitude or zenith distance of a heavenly body, allowance must be made for refraction. Parallax depresses; refraction elevates the body. *See Refraction.* For other allowances, *see Latitude.*

Astronomers recommend, as the best method to find this parallax, two observations taken on the same meridian, one north, the other south of the moon, at some distance apart; Mr. Ferguson says, "at such a distance from each other, that the arch of the celestial meridian included between their two zeniths, may be at least 80 or 90 degrees."

Let *A B D* be a meridian of the earth; (*Plate VII, Fig.* 12.) *C*, its centre; *A*, a place in north latitude; *B*, a place in south latitude. *Z*, the zenith at *A*, *z*, the zenith at *B*, *M* the moon. Let an observer at each of these stations with a good instrument, take the exact zenith distance of the moon's centre, when she passes the meridian.—From the sum of these two zenith distances subtract the sum of the two latitudes, the remainder is the sum of the two parallaxes. In triangle *A B C* the sides *A C* and *B C* are known, being each equal to a semi-diameter of the earth; the angle *A C B* is the sum of the two latitudes; the angle *C A B* is equal to the angle *C B A*, (*Euclid*, *B. I*, *Prop V.*); therefore subtract the angle *A C B* from 180°, and half the remainder is the angle *B A C*, or the angle *A B C*. All the angles therefore, and two sides being given, the side *A B* may be easily found.

The angle *C A M* is the supplement of *Z A M*, and the angle *C B M* is the supplement of *z B M*.

Subtract the angle *C A B* from the angle *C A M*, the remainder is the angle *B A M*; and subtract the angle *C B A* from the angle *C B M*, the remainder is the angle *A B M*. The sum of these angles taken from 180° leaves the angle *A M B*. In the triangle *A M B* all the angles and the side *A B* may be considered as given to find the side *A M*, or *B M* Suppose the side *A M* found. Then in the triangle *A C M*, the sides *A C* and *A M* and the angle between them, *C A M*, being known, the side *C M*, the distance of the moon from the earth, may be easily found by oblique trigonometry.

SECTION III.

PARALLAX OF THE SUN.

Aristarchus, an astronomer of Samos, who flourished about the middle of the third century before Christ, proposed to find the sun's parallax, by observing the instant the moon is dichotomized, or when exactly one half of her disk appears illuminated This is a little before her first, and a little after her last quarter. The moon, as seen from the sun, is then at her greatest elongation, and the angle at the moon is a right angle. The angle, which the distance of the moon from the sun subtends at the earth, is taken by observation. If then the distance of the moon from the earth be known, the parallax is easily ascertained, and the distance of the sun from the earth may be found by a common problem in rectangular trigonometry. But it is impossible to be very accurate in determining the time, when the moon is dichotomized; and a small error in ascertaining this time will make so great a difference in the sun's parallax, that dependence cannot be placed on this method.

Hipparchus proposed, by observing the exact time the moon is in passing the earth's shadow in a lunar eclipse, to obtain a triangle for finding the sun's parallax. But this method, like the former, is subject to great and unavoidable errors. Indeed all attempts to ascertain the parallax of the sun, prior to the seventeenth century, can scarcely be called approximations to the truth. The method then suggested, will be the subject of the following article.

THE TRANSIT OF VENUS.

No improvement in modern astronomy can be compared to that of determining the magnitude and distance of the planets by the transit of Venus. The manner in which this may be effected was first suggested by Dr. Halley. When, in the earlier part of his life, this great astronomer was at the Island of St. Helena, for the purpose of viewing the stars around the south pole, he had an accurate observation of Mercury passing over the disk of the sun. He immediately formed an idea, that such transits might be used for finding the sun's parallax.

But Mercury is too near the sun to be conveniently used for the intended purpose. It is necessary, therefore, to have recourse to *Venus.*

The transit of Venus happens but seldom. Horrox, a young English astronomer, and his friend, Mr. Crabtree, as far as we know, were the first who had a view of the singular and pleasing phenomenon, Venus passing over the sun's disk. This was on the 24th of November, O. S. 1639. But their observations were imperfect, the sun going down, in England, during the transit.

The next transit was on the 6th of June, 1761. Doctor Halley, in a paper communicated to the royal society, in the year 1691, gave particular directions for observing this, and the following transit, in 1769, though he knew they must happen some time after his death.

The exact periodical times and relative distances of the planets ; the heliocentrick or angular motion of the earth and Venus in their orbits, and, of course, the excess of Venus's angular motion over that of the earth ; the latitude of Venus ; the direction and extent of her path over the sun's disk ; and the duration of the transit, as viewed from the centre of the earth, were deduced from observation on her motion, or were calculated before the transit of 1761 ; and may be considered as *data* in any transit.

If the distance of the earth from the sun be assumed at 100,000, the distances of the other principal planets would be,

Mercury	38,947,
Venus	71,578,
Mars	151,579,
Jupiter	515,789,
Saturn	947,368,
Herschel	1,894,736.

When the true distance of the earth from the sun is known, the true distance of the other planets may be easily found; for the great law of Kepler applies, and as the square of the periodical time of the earth is to the cube of its distance; so is the square of the periodical time of another primary planet to the cube of its distance. More concisely; as the relative distance of the earth from the sun is to the true distance, so is the relative distance of any other primary planet from the sun to its true distance.

The apparent motion of a planet in a transit is always retrograde.

The transit of Venus may be taken by one observer. The method given in Enfield's philosophy, seems one of the best for this purpose. The principle is; (*Plate VIII. Fig* 3.) let *S* be the sun, *V A B L M N*, a part of Venus's orbit, *C D*, a part of the earth's orbit; let the observer's station on the earth at *C* be such, that the sun may be on the meridian about the middle of the transit, as calculated for the earth's centre This would be at *a*, had the earth no diurnal rotation. But, on account of such rotation, let it be at *b*, where Venus at *V* is seen at the commencement of the transit at *I*, just entering on the sun's disk. To such an observer, unaffected by diurnal rotation, the egress of Venus would appear at *K*, when she has passed to *B*. But as the observer is carried, during the transit, by such rotation eastward; suppose to *c*, Venus would seem to leave the sun when she arrives at *A*, making the apparent transit shorter than that by calculation in the proportion of *V A* to *V B*. Hence the difference between the observed and computed transit, is the time, in which Venus, by the excess of her heliocentrick motion, would pass from *A* to *B* in her orbit, measuring the angle *A K B* or *c K b*.

The difference of time must be reduced to Venus's heliocentrick motion from the earth. This may be done by proportion; for as one hour is to Venus's heliocentrick horary motion from the earth; so is the difference between the observed and computed duration of the transit, to her motion from the earth during that time, viz. the arch, *A B.*

By knowing the latitude of the place of observation, and the duration of the transit, the length of the line *b c* may be easily obtained, and may be compared with the semi-diameter of the earth. By this comparison, with proper allowances for the direction of the observer's motion and that of Venus, the angle, which a semi-diameter of the earth subtends at the sun, equal to the sun's horizontal parallax, may be obtained.

But, lest the computed duration of the transit should not be perfectly correct, an observer ought to be stationed at or near the meridian opposite the former, and so near the enlightened pole, that the beginning of the transit may be observed before sunset, and the end after sunrise. Such an observer, as seen from the sun or Venus, would appear to move, during the transit, in a direction contrary to the former observer. Let *D* be the place of the earth in its orbit, (*Pl. VIII, fig.* 3,) and *d* the place of the observer at the commencement of the transit, when Venus, at *L*, appears first to touch the sun at *I.* If the observer were stationary at *d*, the transit would end, when Venus arrives at *M.* But during the transit the observer must be carried, by the diurnal motion of the earth, some distance, as to *e*; Venus must, therefore, pass in her orbit to *N*, before her apparent egress from the sun's disk, making the observed transit longer than that by computation. From the difference between the duration of the observed and computed transit, the parallax is obtained as before. If there be an error in the computed duration of the transit, the result of the two operations will be unequal. The error, that increases the one, must diminish the other, so that the mean between the two results may be taken for the exact transit. The mean between many results has been taken, and from them the parallax ascertained to a degree of accuracy, equal, it may seem, to the most sanguine expectation of the scientific Halley.

An accurate method of obtaining the parallax of the sun, by the transit of Venus, may be by two observers 90° from each other, observing the ingress of the planet upon the sun's disk, or egress from the same.* (*Plate VIII, Fig* 4.) Suppose the ingress. Let *S* be the sun in his apparent magnitude; *V A B* a part of Venus's orbit; *C D E* an arch of the equator or parallel of latitude on the earth; *G*, its centre. Let an observer at *C*, be on that meridian, which will pass the sun at or near the beginning of the transit; let another observer be at *E*, on a meridian 90° from *C*. It is manifest, that if there were no diurnal motion to the earth, Venus must pass from *V* to *B*, after her ingress at *I*, on the disk of the sun as seen from *C*, before she would seem to touch the sun as seen from *E*, and the difference of the observed time, allowance being made for longitude, turned into the heliocentrick motion of Venus over that of the earth, would measure the angle *V I B* or *G I E*, viz. the angle which a semidiameter of the earth would subtend at the sun.

But during the interval between the ingress observed at *C* and that at *E*, the observer at *E* must be carried eastward by the diurnal rotation of the earth. Suppose him arrived at *D*, when he first observes Venus indenting the disk of the sun. Venus will then appear to touch the sun at *I*, when she has passed to *A*. In the difference of absolute time between the beginning of the transit, as observed at *C* and that of the observer arrived at *D*, Venus by the excess of her heliocentrick motion will pass from *V* to *A*, measuring the angle *V I A*. The number of degrees in the arch *E D* may be easily known by computation, a degree being allowed for each four minutes of time. The co-sine of the arch *E D* is the line *D F* = *G H*. The length of the line *D F* or *G H* is found by comparing it with the semi-diameter of the earth, as the co-sine of the angle measured by the arch *E D* is to radius. Then as *D F*, or its equal *G H*, is to the time Venus is pass-

* For a suggestion of this method, the author is indebted to a very ingenious Friend.

ing from *V* to *A* by the excess of her motion; so would *G E* be to the time Venus is passing by that excess from *V* to *B*. The arch *V B* measures the angle *V I B*, subtended by *G E*, equal to the semi-diameter of the earth. Allowance must here be made for obliquity of motion in the planet and observer; unless the observer should be so situated, that his motion and that of Venus must be directly opposite.

The angle, which a semi-diameter of the earth subtends at the sun being known, the distance of the earth from the sun may be easily found by rectangular trigonometry; for the angle at *E* is a right angle, the line *E I* being a tangent to the earth's surface, and the semi-diameter of the earth is known. Making the distance radius, say, as the tangent of the angle *G I E*, is to the line *G E*; so is radius to the line *G I*, the distance of the earth from the sun.

In case of two observers, great care must be taken that the time keepers be accurate and regulated on the same principle.

This principle of finding the parallax may be applied to other distances in the places of observation beside 90°; and equally, if both observers be not on the same parallel.

Mr. Short, of London, took great pains in deducing the quantity of the sun's parallax from the best observations made both in Britain and abroad, and found it to have been 8.52″, on the day of the transit, when the sun was near its greatest distance from the earth; and consequently 8 65″, when the sun is at its mean distance from the earth. From this Mr. Ferguson makes 23,882.84 the number of semi-diameters of the earth, which it is distant from the sun. As he reckoned the semi-diameter of the earth 3985 miles, multiplying these together he made the mean distance of the earth from the sun 95,173,127 miles. If we take the semi-diameter of the earth 3982 miles, which it would be, according to Dr. Bowditch, and multiply it by the same number 23,882.84, the result is 95,101,469, for the earth's mean distance from the sun. It is amusing and gratifying, to know what vast interest was felt in the transit of 1761, and what great pains were taken to observe it with accuracy.

"Early in the morning," June 6th, "when every astronomer was prepared for observing the transit, it unluckily happened, that both at London and the royal observatory at Greenwich, the sky was so overcast with clouds, as to render it doubtful whether any part of the transit should be seen; and it was 38 minutes 21 seconds past 7 o'clock, apparent time, at Greenwich, when the Rev. Mr. Bliss, astronomer royal, first saw Venus on the sun."

Mr. Short made his observations at Saville house, London, in the presence of several of the royal family. The transit was observed at several other places in England; at Paris by M. De la Lande. At Stockholm observatory, latitude 59° 20½′ N. longitude 18° east from Greenwich, the whole transit being visible, was observed by Wargentin. It was observed also at Hernosand in Sweden, at Torneo in Lapland, at Tobolsk in Siberia, at Madrass, at Calcutta, and at the Cape of Good Hope. Dr. Maskelyne's observations at St. Helena "were not completely successful on account of the cloudy state of the weather."

The parallax deduced from observations on the transit of 1761, was confirmed by the transit of 1769 without material alteration.

Professor Vince has given the following convenient method of ascertaining when the transits of Mercury and Venus will happen. "The mean time from conjunction to conjunction of Venus or Mercury being known, and the time of one mean conjunction, we shall know the time of all the future mean conjunctions. Observe, therefore, those which happen near to the node, and compute the geocentrick latitude of the planet at the time of conjunction, and, if it be less than the apparent semi-diameter of the sun, there will be a transit of the planet over the sun's disk; and we may determine the periods when such conjunctions happen in the following manner. Let $P =$ the periodic time of the earth, p that of Venus or Mercury. Now that a transit may happen again at the same node, the earth must perform a certain number of complete revolutions, in the same time that the planet performs a certain number, for then they must come into conjunction again at the same point of the earth's orbit, or nearly in the same position in respect to the node. Let the earth perform x revolutions whilst the planet performs y revolutions; then will $P x = p y$, therefore, $\frac{x}{y} = \frac{p}{P}$. Now $P = 365.256$, and for Mercury, $p = 87.968$; therefore $\frac{x}{y} = \frac{p}{P} = \frac{87.968}{365.256}$." From this he ascertained, "that 1, 6, 7, 13, 33, 46, &c. revolutions of the earth are nearly equal to 4, 25, 29, 54, 137, &c. revolutions of Mercury, approaching nearer to a state of equality the further you go. The first period or that of one year is not sufficiently exact; the period of six years will sometimes bring on a return of a transit at the same node; that of seven years more frequently; that of 13 years still more frequently, and so on." For Venus $p = 224.7$; hence $\frac{x}{y} = \frac{p}{P} = \frac{224,7}{365,256}$." From this he makes the periods 8, 235, 713, &c. years. "The transits at the same node will, therefore, sometimes return in 8 years, but oftener in 235, and still oftener in 713."

Those, who wish to be more particular, and calculate or project the transits of these planets, can have recourse to those larger works in astronomy, where the motions of the planets, their aphelia and nodes with secular variations, may be found at length in tables. Their insertion here would exceed the limits designed for this work.

The following table, showing the times of transits, was formed by abridging Dr. Brewster's account of them in his supplement to Ferguson.

TRANSITS.						TRANSITS.					
MERCURY.						VENUS.					
Times of happening			Times of happening			Times of happening			Times of happening		
1707	May	5	1802	November	8	1631	December	6	2490	June	12
1710	November	6	1815	November	11	1639	December	4	2498	June	9
1723	November	9	1822	November	4	1761	June	5*	2603	December	15
1736	November	10	1832	May	4	1769	June	3	2611	December	13
1740	May	2	1835	November	7	1874	December	8	2723	June	15
1743	November	4	1845	May	8	1882	December	6	2741	June	12
1753	May	5	1848	November	9	2004	June	7	2846	December	16
1756	November	6	1861	November	11	2012	June	5	2854	December	14
1769	November	9	1868	November	4	2117	December	10	2984	June	14
1776	November	2	1878	May	6	2125	December	8			
1782	November	12	1881	November	7	2247	June	11			
1786	May	3	1891	May	9	2255	June	8			
1789	November	5	1894	November	10	2360	December	12			
1799	May	7				2368	December	10			

* Astronomical time.

CHAPTER XI.

COMETS.

Comets are large opaque bodies, moving round the sun in various directions, and in very eccentric orbits. It is not wonderful, if, as we are told, comets were considered portentous in the days of barbarism and superstition; if they were regarded as the harbingers of war, famine, and pestilence; if they presented to the frighted imaginations of men the convulsions of states, the dethronement of kings, and the fall of nations. Astronomers of the present day view them in a light entirely different. By the allwise Creator they are without doubt designed for benevolent and important purposes; though most of those purposes must be to us unknown, or deduced only by reasoning from analogy. A comet, when viewed through a good telescope, resembles a mass of aqueous vapour surrounding a dark nucleus, of different shades in different comets; though sometimes no nucleus is observed. Of the last kind were some seen by Dr. Herschel, and some by his sister. As the comet approaches the sun, its nebulous light becomes more brilliant, its luminous train increasing gradually in length. At the perihelion its heat is greatest, and the length of its tail is at its maximum. Here the comet sometimes shines with all the splendor of Venus.—Retreating from the perihelion, its splendor decreases, and it re-assumes its nebulous appearance. "History," says Dr. Rees, "records, that some comets have appeared as large as the sun." Mr. Wilkins mentions one, "said to be visible at Rome, in the reign of the emperor Nero, which was not inferior in apparent magnitude to the sun. The astronomer Hevelius also observed a comet in 1652, which did not appear to be less than the moon, though it was deficient in splendor; having a pale, dim light, and exhibiting a dismal aspect." The number of comets which have been seen within the limits of the solar system is differently stated, from 350 to 500. It is indeed unknown. The orbits or paths of 98* of these up to the year 1808 have been calculated. The time of their passage through the perihelion; longitude of the perihelion and the inclination of the orbits, are inserted in tables. 24 comets have passed between the sun and the orbit of Mercury; 33 between the orbits of Mercury and Venus; 21 between the orbits of Venus and the earth; 16 between the orbits of the earth and Mars; 3 between the orbits of Mars and Ceres; and 1 between the orbits of Ceres and Jupiter.

Various have been the opinions of astronomers respecting the tails of comets. These tails sometimes occupy an immense space in the heavens. The comet of 1681 stretched its tail across 104°; and the comet of 1769 subtended an angle of 60° at Paris, 70° at Boulogne, 97° at the isle of Bourbon. These long trains of light were supposed by Appian, Cordon, and Tycho Brahe to be the light of the sun, transmitted through the nucleus of the comet, which they believed transparent like a lens. Kepler thought, that the impulse of the solar rays drove away the denser parts of the comet's atmosphere, and thus formed the tail. Descartes ascribes the tail to the refraction of light by the nucleus. Newton maintained, that it is a thin vapour raised by the heat of the

*"In 1811 the number of these, whose elements had been calculated, was 103."—*Dr. Morse.*

sun. Euler thinks there is a great affinity between these tails, the zodiacal light and the aurora borealis, and that the cause of them all is the action of the sun's light on the atmosphere of the comets, of the sun, and of the earth. Doctor Hamilton of Dublin supposes the trains of comets to be streams of electrical light. The Dr supports his opinion by these arguments : " A spectator at a distance from the earth would see the aurora borealis in the form of a tail opposite the sun, as the tail of a comet lies. The aurora borealis has no effect upon the stars seen through it ; nor has the tail of a comet. The atmosphere is known to abound with electric matter, and the appeara ce of the electric matter in vacuo resembles exactly that of the aurora borealis, which, from its great altitude, may be considered in as perfect a vacuum, as we can make. The electric matter in vacuo suffers the rays of light to pass through, without being affected by them. The tail of a comet does not expand itself sideways, nor does the electric matter. Hence he supposes the tails of comets, the aurora borealis, and the electric fluid, to be the same kind of matter " In confirmation of this hypothesis, it may be added, that many astronomers have observed an undulatory motion in the trains of comets, similar to what is sometimes seen in the aurora borealis The most extensive aurora borealis, which has appeared for many years in the northern section of the United States, was about the close of the revolutionary war. This with vast undulations covered the whole northern half of the hemisphere, collecting into a beautiful centre in the zenith. To a spectator on a distant planet this might give the earth an appearance, resembling, in some measure. that of a comet.

The following are some of the laws of cometary motion and aspect, observed by astronomers.

" The elliptical orbits of comets have one of their foci in the centre of the sun, and, by radii drawn from the nucleus to the sun, describe areas proportioned to the times "

" Their tails appear largest and most brilliant immediately after their transit through the region of the sun."

"The tails always decline from a just opposition to the sun towards those parts, which the bodies or nuclei pass over, in their progress through their orbits."

"The tails are somewhat brighter, and more distinctly defined in their convex than in their concave parts."

"The tails always appear broader at their upper extreme, than near the centre of the comet."

"The tails are always transparent, and the smallest stars appear through them."

CHAPTER XII.

THE FIXED STARS.

Astronomers seem now agreed, that the fixed stars are suns to other systems. Their immense distance is demonstrable from their always preserving the same unchangeable position in regard to each other, when viewed from different extremes of the earth's orbit. Though the earth is at one season of the year about 190 millions of miles distant from its place at the opposite season, yet the apparent position of the fixed stars is not altered, or, if they have a parallax, it is undetermined by all the observations yet made, and can scarcely exceed a single second. "From what we know," says Mr. Ferguson, "of the immense distance of the stars, the nearest may be computed at 32,000,000,000,000 of miles from us; which is farther than a cannon ball would fly in 7,000,000 of years." From the distance of the stars it may be concluded, that they shine by their own native light, and not by the reflected rays of the sun. For those rays, decreasing in number in any given space, as the squares of the distances increase, cannot by reflected light make objects visible at such an inconceivable distance.

The fixed stars are easily distinguished from the planets by the twinkling of their light. Viewed through a good telescope, the diameter of a star appears much less than when seen by the naked eye. By increasing the power of the telescope, the diameter seems to increase; but not according to any regular proportion.

The number of stars visible to the naked eye in either hemphere is not more than 1000. They seem indeed to be without number, when in a clear evening we turn our eyes towards the heavens. But by looking attentively we shall find, that most of those bright spots, which appeared to be stars, vanish. The British catalogue, including many stars not visible to the naked eye, contains not more than about 3000 in both hemispheres. By improved reflecting telescopes the number is found to be great beyond all conception. " Dr. Herschel says, that in the most crowded part of the milky way, he has had fields of view, that contained no less than 588 stars, and these were continued for many minutes, so that in a quarter of an hour, he has seen 116,000 stars pass through the field of view of a telescope, of only 15 aperture,* and at another time, in 41 minutes, he saw 258,000 stars pass through the field of his telescope. Every improvement in his telescopes has discovered stars not seen before, so that there appear no bounds to their number, or to the extent of the universe."

Many stars, which to an observer unaided by instruments appear single, are found, on being examined by a good telescope, to consist of two, and some times of three or more stars. Those, which are in a great degree removed from the attractive force of other stars, are denominated by Dr. Herschel " insulated stars," such are our sun, Arcturus, Capella, Sirius, and many others.

" A binary sidereal system or double star, properly so called, is formed by two stars situated so near each other, as to be kept together by their mutual gravitation." It is manifest, that stars, one being nearly behind the other, may appear binary, though immensely distant.

The double star *Epsilon*, Bootes, is beautiful, composed of two stars, one a light red, the other a fine blue.

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* So state the books. We are not told his manner of counting.

Plate XI, Fig. 5. represents this beautiful double star as seen by telescopes of different magnifying powers.

The double star *Zeta* Herculis is composed of a greater and a less, the former of a beautiful blueish white, the latter of a fine ash colour.

The star *Delta* of the Swan is composed of two stars very unequal, the larger, white, the less, reddish.

The *Alpha* Hercules consists of two stars very unequal, the larger, red, the less, blueish green.

Viewed by three different telescopes these stars appear as in *Plate XI, Fig.* 4.

The pole star, the Alpha of the little Bear, is binary, consisting of two stars extremely unequal in magnitude, the larger white, the less red.

In *Plate XI, Fig.* 6, is represented one of the most beautiful objects of this kind in the heavens, the treble star in the left fore foot of the constellation Monoceros. Viewed with attention it appears a double star; with still more attention, one of the component stars appears also double.— All are white.

Beta Lyræ is quadruple, unequal white; but three of them a little inclined to red.

Lambda Orionis is quadruple, or rather a double star, having two more at a small distance, the double star unequal, the largest white; the smallest a pale rose colour.

A catalogue of the principal double stars may be seen in Dr. Brewster's Supplement to Ferguson. Its insertion here would exceed the limits designed for this work.

The stars have been arranged into six classes, or orders, according to their magnitude. The largest are called stars of the first magnitude; those next to them, stars of second magnitude, and so on to the sixth. Considerable difference, however, may be perceived in the stars of each magnitude, some being much larger and more brilliant than others The arrangement of the stars into magnitudes was made long before the invention of telescopes. Stars not seen without these are called telescopic stars. In books of modern astronomy we sometimes find stars mentioned of the seventh or eighth magnitude.

Besides the arrangement of the stars into magnitudes, the ancients divided the starry sphere into constellations, or systems, each including stars of different magnitudes. By a powerful imagination, they conceived companies of stars as having the form of certain animals or things, and applied names accordingly to such companies. Thus one constellation is called Aries ; another, Cassiopeia ; and another, Orion.

In *Plate X*, *Figures* 1, 2, 3, and 4, may be seen Ursa Major, Leo, Cygnus, and Lyra, four of the constellations as they are represented on a 12 inch celestial globe. From these, as a specimen, the student may form some idea of that imagination, by which they were arranged. Probably in Ursa Major or any other constellation viewed in the heavens, he will see but little similarity between the figure presented by the stars and the animal by which they are represented.

Figures 7, 8, and 9, of *Plate XI*, represent the stars of Orion, Bootes, and Canis Major, as they are arranged on a celestial globe.

Stars not included in any constellation, are called unformed stars. The classing of the stars is of great antiquity. It is also, however chimerical, of vast importance, as it enables the astronomer to describe the place of a star, a planet, or comet at any time, as easily as a geographer can that of a hamlet or a town. The number of ancient constellations is 48. Of these, 12 were within the zodiac, 21 to the north, and 15 to the south of it. The animal or object of each constellation is represented on the celestial globe ; and the proportion of the stars belonging to each denoted by the letters of the Greek alphabet, according to the plan adopted by M. Bayer, a German, in his " Uranometria," a large celestial atlas. Thus, *alpha* is placed to the largest star of the constellation, *beta* to the second, *gamma* to the third, and thus on in alphabetical order.

Tables containing the constellations, with the number of stars in each, observed by the different astronomers, Ptolemy, Tycho, Hevelius, and Flamstead.

CONSTELLATIONS IN THE ZODIAC.

NAMES OF CONSTELLATIONS.	No. of Stars. Pto.	Tyc.	Hev.	Fla.	Chief stars.	Magnitudes.
Aries, the Ram	18	21	27	66		
Taurus the Bull	44	43	51	141	Alde-baran	1
Gemini the Twins	25	25	38	85	Castor & Pollux	1 2
Cancer, the Crab	13	15	29	83		
Leo, the Lion with corona Berenices	35	30	49	95	Regulus	1
Virgo, the Virgin	32	33	50	110	Spica virginis	1
Libra, the Scales	17	10	20	51	Zubenich Meli	2
Scorpio, the Scorpion	24	10	20	44	Antares	1
Sagittarius, the Archer	31	14	22	69		
Capricornus, the Goat	28	28	29	51		
Aquarius, the Water bearer	45	41	47	108	Scheat	3
Pisces, the Fishes	38	36	39	113		

NORTHERN CONSTELLATIONS.

NAMES OF CONSTELLATIONS.	No. of stars. Pto.	Tyc.	Hev.	Fla.	Chief stars.	Magnitude.
Ursa Minor the little Bear	8	7	12	24	Pole-star	2
Ursa Major, the great Bear	35	29	73	87	Dubhe	1
Draco, the Dragon	31	32	40	80	Rastaber	3
Cepheus	13	4	51	35	Alderamin	3
Bootes	23	18	52	54	Arcturus	1
Corona borealis, the northern Crown	8	8	8	21		
Hercules engonasia	29	28	45	113	Ras Algiatha	3
Lyra, the Harp	10	11	17	21	Vega	1
Cygnus, the Swan	19	18	47	81	Deneb Adige	1
Cassiopeia, the Lady in her chair	13	26	37	55		
Perseus	29	29	46	59	Algenib	2
Auriga, the Waggoner	14	9	40	66	Capella	1
Serpentarius	29	15	40	74	Ras Alhagus	3
Serpens, the Serpent	13	13	22	64		
Sagitta, the Arrow	5	5	5	18		
Aquila, the Eagle }	15	12	23	71	Altair	1
Antinous }		3	19			
Delphinus, the Dolphin	10	10	14	18		
Equulus, Equisortio, the Horse's head	4	4	6	10		
Pegasus, the flying Horse	20	19	38	89	Markab	2
Andromeda	23	23	47	66	Almaac	2
Triangulum, the Triangle	4	4	12	16		
Canes Vanatici, the Grey hounds			23	25		
Cor Caroli, the heart of Charles				3		
Triangulum minus, the little Triangle				10		
Musca, the Fly				6		
Lynx, the Lynx			19	44		
Leo Minor, the little Lion				53		
Camelopardalis			32	58		
Mons Menelaus				11		
Scutum Sobieski, Sobieski's Shield			7	8		
Hercules cum Ramo and Cerbero						
Taurus Poniatowski				7		
Vulpeculus et Anser, the Fox and Goose			27	37		
Lacerta, the Lizard				16		

SOUTHERN CONSTELLATIONS.

NAMES OF CONSTELLATIONS.	No. of Stars. Pto.	Tyc.	Hev	Flam.	Chief Stars.	Magnitude
Cetus, the Whale	22	21	45	97	Menkar	2
Orion	38	42	42	78	Betelgeuse	1
Eridanus	34	10	27	84	Archenar	1
Lepus, the Hare	12	13	16	19		
Canis Major, the great Dog	29	13	21	31	Sirius	1
Canis Minor, the little Dog	2	2	13	14	Procyon	1
Argo, the Ship	45	3	4	64	Cunopus	1
Hydra, the water Serpent	27	19	31	60	Cor Hydraf	1
Crater, the Cup	7	3	10	31	Alkes	3
Corvus, the Raven	7	4	0	9	Algorab	3
Centaurus, the Centaur	37			35		
Lupus, the Wolf	19			24		
Ara, the Altar	7			9		
Corona Australis, the southern Crown	13			12		
Pisces Australis, the southern Fish	18			24	Fomalhaut	1
Phœnix				13		
Officina sculptoria				12		
Hydrus, the Watersnake				10		
Fornax chemica, the chemical Furnace				14		
Horologium, the Timekeeper				14		
Reticulus Rhomboidalis				10		
Xiphias Dorado, the Swordfish				7		
Cela Praxitellis				16		
Columba Noachi, Noah's Dove				10		
Equuleus pictorius, the painted Colt				8		
Monoceros, the Unicorn			19	31		
Chameleon				10		
Pyxis Nautica, the Mariner's Compass				4		
Piscis volans, the flying Fish				8		
Sextans, the Sextant			11	41		
Robur Carolinum the royal oak				12		
Machina Pneumatica, the wind Instrument				3		
Crosiers, el Cruzero				6		
Apis Musca, the Bee or Fly				4		
Apus or Aries Indica, the Bird of Paradise				11		
Circinus, the Compass				4		
Quadra Euclidis, Euclid's Square				12		
Triangulum Australis, the southern Triangle				5		
Telescopium, the Telescope				9		
Pavo, the Peacock				14		
Indus, the Indian				12		
Microscopium, the Microscope				10		
Octans Hadleianus, Hadley's Octant				43		
Grus, the Crane				14		
Toucan, the American Goose				9		

The whole number of constellations is now 92, of which 12 are in the Zodiac ; 35 are northern, 45 southern. Probably the number may yet be increased. The ancient constellations are placed first in each table.

Several stars have appeared in the heavens for a time, and then disappeared. Several are enumerated in ancient catalogues, which are no longer to be seen, even by the powerful instruments of modern astronomy. Others are now visible, which do not appear to have been seen by the ancients.

In 1572, a new star was discovered by Cornelius Gemma, in the chair of Cassiopeia. In brightness and magnitude, it surpassed Sirius. To some eyes it appeared larger than Jupiter, being seen at mid day. It afterwards gradually decayed, and, after sixteen months, disappeared.

In 1596, Fabricius observed the *Stella Mira*, or wonderful star, in the neck of the whale. It seemed to appear, and disappear seven times in six years ; though it is said never to have been wholly extinct.

In the year 1600, Jansenius observed a changeable star in the neck of the swan. It was observed by Kepler, who determined its place, and wrote upon it. The same was seen by Ricciolus, in 1616, 1621, and 1624 ; but was invisible from 1640 to 1650. It was seen again in 1655, by Cassini. It increased till 1660 ; then decreased till the end of 1661, when it disappeared. In November, 1665, it again became visible, but disappeared in 1681. It again appeared, in 1715, as a star of the sixth magnitude. This is its present appearance.

In 1604, Kepler and some of his friends discovered a new star, near the head of Serpentarius, bright and sparkling, beyond any they had before seen. It appeared every moment changing, assuming the different colours of the rainbow, except, when near the horizon, it was generally white. In October of that year it was near Jupiter, surpassing that planet in magnitude, but before the following February it disappeared.

Many other stars have appeared, vanished, and re-appeared ; some of them in regular returns.

Such changeable stars may be suns with extensive spots. By a rotation on their axes, stars of this kind may alternately present their dark and luminous sides. "Maupertius is of opinion, that some stars, by their prodigious quick rotation on their axes, may not only assume the figure of oblate spheroids, but by their great centrifugal force, arising from such rotation, they may become of the figures of millstones, or reduced to flat circular planes, so thin as to be quite invisible; when their edges are turned towards us; as Saturn's ring is in such positions. But, when any excentric planets or comets go round any flat star, in orbits much inclined to its equator, the attraction of the planets or comets in their perihelions, must alter the inclinations of that star; on which account it will appear more or less large and luminous, as its broad side is more or less turned toward us."—*Ferguson.*

The observations of modern astronomers would render doubtful the term fixed, as applied to the stars. An advancement of the solar system in absolute space is now considered certain. It was observed by Halley and Cassini. The first explanation of it was given by Mayer. But to Dr. Herschel it was reserved to point out the region in the heavens, to which the solar system is advancing. "Dr. Herschel has examined this subject with his usual success, and he has certainly discovered the direction, in which our system is gradually advancing. He found, that the apparent proper motion of about 44 stars out of 56 is very nearly in the direction, which would result from a motion of the sun towards the constellation Hercules, or, more accurately to a place in the heavens, whose right ascension is 250° 52′ 30″, and whose north polar distance is 40° 22′."

THE GALAXY.

The Galaxy, or Milky way, is a luminous zone in the heavens. Its beautiful, cloudy whiteness is found by modern astronomers to be caused by the collected rays of innumerable stars, not discernible by the naked eye. "That the milky way," says Dr. Herschel, "is a most extensive stratum of stars of various sizes, admits no longer of the least doubt."

A group of stars is a collection of stars, closely compressed, and of any figure.

Clusters of stars, (*Plate X. Fig.* 6) differ from groups, in their beautiful and artificial arrangement ; regarded by Dr. Herschel among the most magnificent objects in the heavens.

Nebulæ, or cloudy stars, are bright spots in the heavens, (*Plate XI. Fig.* 1, 2, *and* 3.) Some of them are found to be clusters of telescopic stars. The most noted nebula is between the two stars in the sword of Orion, discovered by Huygens in 1656. It contains seven stars, and in another part, a bright spot upon a dark ground, seeming to be an opening into a brighter and more distant region, (*Plate XI. Fig.* 1.) Nebulæ were discovered by Dr. Halley and others. A catalogue of 103 nebulæ, discovered by Messier and Meihain, is inserted in the *Connoisance de tems*, for 1783 and 1784. " But to Dr. Herschel," says Enfield, " are we indebted for catalogues of 2000 nebulæ and clusters of stars, which he himself has discovered." Dr. Brewster says 2500.

We cannot contemplate the fixed stars without repeating the sentiment expressed in the introduction ; without admiration and astonishment ! How inconceivably Great and Wise and Good must be the AUTHOR and GOVERNOR of all these ! We behold, not one world only, but a system of worlds, regulated and kept in motion by the sun ; not one sun and one system only, but millions of suns and of systems, multiplied without end, never conflicting, always revolving in harmonious order !

CHAPTER XIII.

REFRACTION.

Refraction of light is the incurvation of a ray from its rectilinear course, in passing from a medium into one of different density. On entering a denser medium, a ray coming obliquely is turned towards the perpendicular drawn to its surface. But it is turned from the perpendicular, to the surface of a rarer medium, when passing from one more dense. An object always appears in the direction, in which a ray of light from it meets the eye of the observer ; though before it may have passed in different directions. Let *A B C D*, (*Plate VIII*, *Fig*. 7.) be a vessel filled with water up to the line *E F*, and the remainder filled with spirit, or other transparent fluid, less dense than water. Let a ray of light be reflected from an object *a* at the bottom in the direction *a I*. This ray in passing from the water into the fluid less dense would be refracted from the perpendicular to the water's surface in a new direction, as to *H*, where the object at the bottom, without further refraction, would appear at *b*. But on leaving the rarer medium at the surface, *A B*, it is again refracted, and again passes in a new direction, as to *G*. So that an eye at *G* must see the object *a* at *c*.

A straight rod appears crooked, when partially immersed in water, viewed obliquely to its surface. Put a piece of money into a bowl, (*Plate VIII*, *Fig*. 5.) and retire till the money is just hidden by the edge of the bowl ; let an attendant pour water into the bowl, the money will rise into view.—When the eye is perpendicular to the surface of the medium, there is no refraction. In wading a river, the water, where you are, appears of its proper depth ; but at a little distance forward it seems more shallow, than on trial it will be found. It has been said, no doubt with truth, that this circumstance has often been the cause of drowning.

The light of heavenly bodies is refracted by the atmosphere of the earth. (*Plate V*, *Fig*.5.) This refraction, greatest at the horizon, decreases towards the zenith, where it becomes nothing. When a medium is throughout equally dense, the refraction is at the surface. But the atmosphere increases in density from its utmost height to the surface of the earth. A ray of light must therefore be more and more bent, and pass in a curvilinear course through the atmosphere. The refraction brings up a heavenly body, before it arrives at the horizon. Let *A B C* (*Plate VIII*, *Fig*. 9.) be a part of the earth's atmosphere, *B F*, the sensible horizon to a spectator at *B*, *D* a place of the sun below the horizon. Suppose a ray of light, passing in the direction *D F*, should strike the atmosphere at *F*. This would be refracted by the increased density of the air all the way from *F* to the surface of the earth, as to *B* ; and would present the sun in the line of its last direction, *B E*. The sun would, therefore, appear in the horizon, before it arrived at that circle.

Cold increases the density of the air, and of course the refracting power. In general, the higher the latitude the greater the refraction. Mr. Ferguson tells us, that the sun arose to some Hollanders, who wintered in Nova Zembla, in 1596, seventeen days sooner, than by calculation it would have been above the horizon.

As the horizontal refraction in latitude 43°, is about 33′, the sun's mean diameter about 32,′ the sun must be visible, when more than his whole breadth below the horizon. The horizon in such latitude passing these 33′ obliquely, and requiring about three minutes of time, the sun is about three minutes in the morning and three at night, longer above the horizon on account of the refraction, increasing the length of the day about six minutes. The refraction of the atmosphere is sometimes the cause of a curious phenomenon, the sun and moon both visible, when the moon is eclipsed by the earth's shadow. Mr. Phillips mentions an instance of this kind, observed at Paris in 1750.

The progressive motion of light has been shown to be another cause, why a heavenly body does not appear in its true place. But this does not alter the length of the day ; for as the sun appears below its true place in the morning, it appears above it at night, leaving the length of the day unaffected.

The disk of the sun or moon appears elliptical, when in or near the horizon. The lower limb being more refracted than the upper, not only by the atmosphere itself, but often by the floating vapour, the outline of the disk must be changed from a circle to an elliptical form.

The table of refraction, here inserted, is that of Dr. Bradley, extracted from Enfield. It agrees very nearly with Mr. Bowditch's table of refraction as set to degrees.

MEAN ASTRONOMICAL REFRACTIONS IN ALTITUDE.

App. alt.	Refraction	app. alt.	Refraction.	app. alt.	Refraction.	app. alt.	Refraction.	app. alt.	Refraction.	app. alt	Refraction
°	′ ″	°	′ ″	°	′ ″	°	′ ″	°	′ ″	°	′ ″
0	33 0	11	4 47	23	2 14	35	1 21	48	51	78	12
1	24 29	12	4 23	24	2 7	36	1 18	50	48	80	10
2	18 35	13	4 3	25	2 2	37	1 16	52	44	82	8
3	14 36	14	3 45	26	1 56	38	1 13	55	40	85	5
4	11 51	15	3 30	27	1 51	39	1 10	58	35	88	2
5	9 54	16	3 17	28	1 47	40	1 8	60	33	89	1
6	8 28	17	3 4	29	1 42	41	1 5	62	30	90	0
7	7 20	18	2 54	30	1 38	42	1 3	65	26		
8	6 29	19	2 45	31	1 35	43	1 1	68	23		
9	5 48	20	2 35	32	1 31	44	59	70	21		
10	5 15	21	2 27	33	1 28	45	57	72	18		
		22	2 20	34	1 24			75	15		

CHAPTER XIV.

TWILIGHT.

The *twilight* is the result of refraction. The atmosphere of the earth extends about 45 miles above the surface ; or at that height is sufficiently dense to refract the rays of the sun. Hence it is found, that when the sun is about 18° below the horizon, the morning twilight will begin, and the evening twilight end. It is said however, that the evening twilight is longer than that of the morning. This may be owing to the elevation of the atmosphere by the heat of the day, and also to the vapour exhaled by rarefaction.

The continuance of twilight, increasing with the distance from the equator, must be very long in high latitudes. At the poles the sun is never more than about 23° 28′ below the horizon. To a polar inhabitant, if any, it must be more than 50 days after the sun sets, before it will be 18° below the horizon; and the same time, on its return, after it approaches within 18°, before it will be above the horizon.

Here we must be led to contemplate with admiration the immense benefit of the atmosphere. Not only by the chemical operations of air, does it cause our blood to flow, and diffuse warmth through our bodies; but, by its reflecting and refracting powers, it gives beauty to our day, and enlarges its borders, even into the regions of night. Astronomers generally concur with Dr. Keill; "That it is entirely owing to the atmosphere, that the heavens appear bright in the day time. For without it, only that part of the heavens would be luminous in which the sun is placed, and, if we could live without air, and should turn our backs to the sun, the whole heavens would appear as dark as in the night. In this case also, we should have no twilight, but a sudden transition from the brightest sunshine to dark night, immediately upon the setting of the sun, which would be extremely inconvenient, if not fatal to the eyes of mortals."

CHAPTER XV.

ZODIACAL LIGHT.

Zodiacal light seems to have been seen by Descartes in 1659, yet it attracted no general notice, till observed by Cassini in the year 1693, when it received its present name. This light, less brilliant than the milky way, appears at certain seasons of the year, in the morning before the rising of the sun, and at evening, after the setting of that luminary.— "It resembles a triangular beam of light, rounded a little at the vertix." It lies in the direction of the zodiac, its base turned towards the sun, and resting on the horizon. About the first of March at 7 o'clock in the evening is the best time for observing this light. This luminous cone is of vast extent, stretching to 45° ; according to some, at times even beyond the meridian. This light, according to Foulquier, is always seen at Gaudaloupe, when the weather admits.

Some have accounted for this phenomenon by the action of the sun's light on his own atmosphere ; others by the refraction of his rays in the atmosphere of the earth. If the former opinion be correct, the bright cone must stretch to an immense distance, when not exceeding 45° it must, if perpendicular to the view of the observer, be equal to the whole distance of the sun from the earth. But its being seen in one part of the earth rather than in another, equally in view, seems to indicate that it must originate in the atmosphere of the earth, and not in that of the sun.

CHAPTER XVI.

LATITUDE AND LONGITUDE ON THE EARTH.

The great circles of the globe are considered as extended into the visible heavens, the celestial circles always lying in the same plane with those on the earth. Hence the position of the heavenly bodies, in regard to these circles, may be used in determining the latitude and longitude of places on the earth.

SECTION I.—LATITUDE.

LATITUDE, as before stated, is the distance north or south from the equator. It is reckoned in degrees and minutes on a meridian. The centre of this circle, as that of the equator and other great circles, is considered at the centre of the earth.

The latitude of a place may be determined by ascertaining the distance of its zenith from the celestial equator. If, therefore, the declination and zenith distance of a heavenly body be known, the latitude of the place of observation may be determined.

The declination of a heavenly body, as before defined, is its distance from the celestial equator, either north or south.—At sea, the meridian zenith distance of a body in the heavens may be obtained by observing its altitude when on the meridian, or by two altitudes. When the altitude of the sun or moon are taken, four corrections are required, *semi-diameter, parallax, depression of the horizon, and refraction.* In a planet, the semi-diameter and parallax can be but a few seconds.—In a star, they are imperceptible. *For the semi-diameter of the sun or moon, see Table 15th. For parallax, depression of the horizon, and refraction, see those articles.*

On land, the irregularity of the sensible horizon renders it necessary to have recourse to an artificial horizon. This may be made of mercury, molasses, or other fluid not easily affected by the wind. Such horizon does not necessarily require allowance for depression of the horizon, as it may have the same elevation as the eye of the observer.

Suppose, that on the 4th of July, 1825, the sun's declination by tables 10th, 11th, and 12th, was found to be 22° 53′ 40″, when it passed the meridian of New-York, and at that time the sun's true zenith distance, after proper allowances, was found to be 17° 48′ 20″, what was the latitude of the place of observation?

Zenith distance	17° 48′ 20″
Declination	+ * 22° 53′ 40″
Answer	40° 42′ 0″

Suppose Sirius, or the Dog star, at 16° 30′ south declination, observed to pass the meridian of a place with a zenith distance of 56° 27′, what is the latitude of the place ?

Zenith distance	56° 27′
Declination	—16° 30′
Answer	39° 57′

The latitude of a place may be determined by observing the altitude of its elevated pole. This altitude is always equal to the latitude of the place. The north pole of the earth at present points nearly to a particular star, called from this circumstance, the pole star. Dr. Flint, in his "Survey," makes the declination of this star, on the first of January, 1810, 88° 17′ 28″, increasing 19. 5 annually. Hence its declination, January 1st, 1825, was 88° 22′ 20″, and its distance from the pole 1° 37′ 40″. Take the altitude of this star above and below the pole. Add these altitudes, and half their sum is the altitude of the pole, and, of course, the latitude of the place.

The pole star is of the same altitude of the pole, when at its greatest elongation from the pole, east or west. To obtain the greatest elongation, observe that the star Alioth of the constellation Ursa Major, or the Great Bear, the pole star, and the star Gamma of Cassiopeia, are nearly in a line.— When this line is in a horizontal direction, or perpendicular to the plane of the meridian, the pole star is at its greatest elongation, east or west, being on the side of the pole next to the Gamma of Cassiopeia and opposite to Alioth. Hence it is east, when Alioth is west, and it is west when Alioth is east.

* The student's judgment, with a little attention, will easily determine, whether in the zenith distance and declination he ought to add or subtract.

For practical methods of obtaining the latitude of places, see Dr. Bowditch's standard work, "The new American Practical Navigator."

SECTION II.

LONGITUDE.

The best method of determining *longitude* has long been a *desideratum* with the public. It has excited the attention not only of the mariner, but of the geographer, the mechanic, the statesman and the philosopher.

We are informed, that Philip III, king of Spain, was the first who offered a reward* for the discovery of longitude.—The States of Holland, then the rival of Spain, as a maritime power, soon after followed the example. The regent of France, during the minority of Lewis XV. offered a great reward for the discovery of longitude at sea. In the time of Charles II. of England, about they ear 1675, a royal observatory was built at Greenwich, and, by the intercession of Sir Jonas Moore, Mr. Flamstead was appointed astronomer royal. Instructions were given to him, and his successors, "That they should apply themselves with the utmost care and diligence to rectify the tables of the motions of the heavens, and the places of the fixed stars, in order to find out the so much desired longitude at sea, for the perfecting of the art of navigation."

The British parliament, in the year 1714, offered a reward for the discovery of longitude, "the sum of 10,000*l.* if the method determined the longitude to 1° of a great circle, or 60 geographical miles; of 15,000*l.* if it determined it to 40 miles; and of 20,000*l*, if it determined it to 30 miles, with this proviso, that if any such method extend no further than

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* A hundred thousand crowns.

80 miles adjoining to the coast, the proposer shall have no more than half such reward. The act also appoints the first lord of the admiralty, the speaker of the house of commons, the first commissioner of trade, the admirals of the red, white, and blue squadrons, the master of Trinity house, the president of the royal society, the royal astronomer at Greenwich," and several others, "as commissioners for the longitude at sea." On this act, Mr. John Harrison received the premium of 20,000*l.* for his "time-keeper." Several other acts were passed in the reigns of George II. and George III. for the encouragement of finding longitude. In the year 1774, an act passed repealing all the former acts respecting the finding of longitude, "and offering separate rewards to any person, who shall discover the longitude, either by the lunar method, or by a watch keeping true time, within certain limits, or by any other method. The act proposes, as a reward for a time-keeper, the sum of 5,000*l.* if it determine the longitude to 1°, or 60 geographical miles; the sum of 7,500*l.* if it determine the same to 40 miles; and the sum of 10,000*l.* if it determine the same to 30 miles, after proper trials specified in this act." This, we are informed, is the last act of the British parliament on the subject.

The United States have not been inattentive to the subject of longitude; so far, at least, as respects establishing a first meridian for themselves. As early as the year 1809, Mr. William Lambert of Virginia presented a memorial to Congress on the subject. He commences his memorial by stating, "That the establishment of a first meridian for the United States of America, at the permanent seat of Government, by which a farther dependence on Great-Britain, or any other foreign nation, for such a meridian, may be entirely removed, is deemed to be worthy the consideration and patronage of the national legislature." In March, 1810, a select committee of the House of Representatives, of which Mr. Pitkin of Connecticut was chairman, made an interesting report on Mr. Lambert's memorial. An extract from it is deemed pertinent to the subject.

" The committee have deemed the subject worthy the attention of Congress, and would, therefore beg leave to observe, that the necessity of the establishment of a first meridian, or a meridian, which should pass through some particular place on the globe, from which geographers aud navigators could compute their longitude, is too obvious to need elucidation.

The ancient Greek geographers placed their first meridian to pass through one of the islands, which by them were called the Fortunate Islands, since called the Canaries.—Those islands were situated as far west as any lands that had then been discovered, or were known by ancient navigators in that part of the world.

They reckoned their longitude east from Hera, or Junonia, supposed to be the present island of Teneriffe.

The Arabians, it is said, fixed their first meridian at the most westerly part of the continent of Africa. In the fifteenth and sixteenth centuries, when Europe was emerging from the dark ages, and a spirit of enterprise and discovery had arisen in the south of Europe, and various plans were formed, and attempts made, to find a new route to the East Indies, geographers and navigators continued to calculate longitude from Ferro, one of the same islands, though some of them extended their first meridian as far west as the Azores, or Western Islands.

In more modern times, however, most of the European nations, and particularly England and France, have established a first meridian to pass through the capital, or some place in their respective countries, and to which they have lately adapted their maps, charts, and astronomical tables.

It would, perhaps, have been fortunate for the science of geography and navigation, that all nations had agreed upon a first meridian, from which all geographers and navigators might have calculated longitude ; but as this has not been done, and, in all probability, never will take place, the committee are of opinion, that, situated as we are in this western hemisphere, more than three thousand miles from any fixed or known meridian, it would be proper, in a national point of view to establish a first meridian for ourselves; and that measures should be taken for the eventual establishment of such a meridian in the United States.

In examining the maps and charts of the United States, and the particular states, or their sea coasts, which have been published in this country, the committee find, that the publishers have assumed different places in the United States as first meridian. This creates confusion, and renders it difficult, without considerable calculation, to ascertain the relative situation of places in this country. This difficulty is increased by the circumstance, that in Louisiana, our newly acquired territory, longitude has heretofore been reckoned from Paris, the capital of the French empire.

The exact longitude of any place in the United States being ascertained from the meridian of the observatory at Greenwich, in England, a meridian with which we have been conversant, it would not be difficult to adapt all our maps, charts, and astronomical tables, to the meridian of such place. And no place, perhaps, is more proper than the seat of government."

The memorial, the report of the committee, and papers accompanying were afterwards referred to Mr. Monroe, the late President of the United States, then Secretary of State. In his report he says: "The Secretary of State has no hesitation to declare his accord with the committee, in their opinion in favour of the establishment of a first meridian for the United States, and that it should be at the city of Washington, the seat of government."

"The United States have considered the regulation of their coin and their weights and measures attributes of sovereignty. The first has been regulated by law, and the second has occasionally engaged their attention. The establishment of a first meridian appears in a like view, to be not less deserving of it; at least, until by common consent, some particular meridian should be made a standard."

In accordance with this sentiment was that of a committee of the House of Representatives, of which Dr. Samuel L. Mitchell, of New-York, was chairman, and to which the subject was again referred.

To these high authorities may be added that of the illustrious Washington, as stated by Mr. Lambert in his address to the President of the United States on the subject, in 1821.

"The illustrious personage, by whose name the metropolis of the American Union has been designated, unquestionably intended that the Capitol, situated at, or near, the centre of the District of Columbia, should be a first meridian for the United States, by causing, during the first term of his Presidency, the geographical position of that point, in longitude 0° 0′, and its latitude 38° 53′ north, as found by Mr Andrew Ellicott to the nearest minute of a degree, to be recorded in the original plan of the city of Washington."

The apparent, or relative time, differs one hour for every 15° of longitude, or four minutes for a degree. To the east it is later, to the west, earlier. When it is noon with us, it is one P. M 15° east; eleven A M 15° west Washington is 76° 55′ 30″ west of Greenwich. When it is noon at Greenwich it is 6h 52m. 18s. A. M. at Washington. Calcutta is 163° 32′ east of Philadelphia. When it is noon at Philadelphia, it is 10h. 54m. 8s. P. M. at Calcutta If, therefore, by observation on the heavenly bodies, or other methods, the time of day at the meridian, from which the longitude is reckoned, can be known, and also the time at the place of observation, the difference turned into motion, by Table 16, will show the longitude.

One method of determining longitude is by a good timekeeper, clock or watch. Such timekeeper, set for any meridian, will not correspond with the apparent time, when carried east or west. But its difference from the apparent time, at the place of observation, would show the difference of longitude, if perfect dependence could be placed on such time-keeper. None, however, has yet been invented, on which perfect reliance can be placed, at all times and in all places. Even the time-keeper of William Harrison, which had made a voyage from England to Barbadoes, and back, varying but 54 seconds in 156 days, or, as was thought with proper allowance, only 15 seconds in that time, was found subject to considerable error, when tried at the royal observatory, by Dr. Maskelyne.

Eclipses of the moon early attracted attention, as a means of finding longitude. The moon being deprived of her borrowed light by immersion in the earth's shadow, all to whom she is visible must see the beginning and end of a lunar eclipse, at the same absolute time. The difference, therefore, of apparent time, as before shown, converted into motion, will give the longitude. "But it is not easy to determine the exact moment, either of the beginning or ending of a lunar eclipse, because the earth's shadow, through which the moon passes, is faint and ill defined about the edges." It is considered, that the rays of light, refracted in the atmosphere of the earth, render the moon visible in the midst of a central eclipse. These rays being more dense near the edges of the shadow, must render the extremes very uncertain.

Eclipses of the sun may be used for determining longitude. These with proper allowances may form an accurate method. But they happen seldom, and require a nicety of calculation. They are considered of but little practical utility.

Eclipses of Jupiter's satellites have been before mentioned, as forming another method of determining longitude. These like those of the moon are seen at the same absolute time at all places, where they are visible. From the difference of apparent time, therefore, the longitude may be deduced.—Happening very often, they form an excellent method of determining longitude on land But it is said the difficulty of observation renders them of but little practical utility at sea.

Another method of determining longitude, of great practical importance, is by *Lunar observations.* "This method of finding the longitude is the greatest modern improvement in navigation. The idea, however, is not modern, but it has not been applied with any success until within the last fifty years. M. de la Lande mentions certain astronomers, who, above two hundred years ago, proposed this method, and contended for the honour of the discovery ; but its present state of improvement and universal practice, he very justly ascribes to Dr. Maskelyne. The discovery, indeed, seems to claim less honor than its subsequent improvements. It is one of those things which are obvious in theory but difficult in practice."

When John Morin, professor of mathematics, at Paris, proposed to Cardinal Richelieu, in the year 1635, a method of solving the problem respecting the longitude, very similar to the lunar method now in use, it was rejected as of no practical utility.

Dr. Maskelyne first proposed and superintended the construction of the Nautical almanack. In this is inserted the angular distance of the moon from the sun and certain fixed stars for the beginning of every third hour in the day, calculated for the meridian of Greenwich. We are not to understand, however, that these distances are such as they would appear to an observer at Greenwich, but at the centre of the earth. They are calculated for Greenwich time. "*If therefore, under any meridian, a lunar distance be observed, the difference between the time of observation and the time in the almanack, when the same distance was to take place at Greenwich, will show the longitude.*" When the distance would be the same at Greenwich, can be easily found by calculation. For the distance being computed, and set down in the almanack for every three hours, any particular distance can easily be found by proportion, the irregularity of the moon's motion, affecting but little for a short intervening time between the times specified in the almanack. In these observations great care must be taken to apply the corrections for parallax, refraction, and depression.

The Nautical almanack is annually published by the commissioners of longitude in England. The stars selected for this almanack are nine, viz.

Stars.	*Constellations.*
Alpha*	Aries
Aldebaran	Taurus
Pollux	Gemini
Regulus	Leo
Spica	Virgo
Antares	Scorpio
Altair	Aquila
Fomalhaut	Pisces Australis
Markab	Pegasus

Except near the time of new moon the angular distance of the moon from these, and from the sun, may be taken at any season, when the weather is clear, and the objects more than 8 or 10 degrees above the horizon.

For practice in finding longitude with the necessary tables, the student is again referred to Dr. Bowditch's useful work, the "Practical Navigator."

While degrees of latitude remain of equal length, in every part of the earth, except a small variation on account of the earth's spheroidical figure, those of longitude decrease from the equator to the poles, where they become extinct. To find the extent of a degree of longitude at any degree of latitude, the proportion is, as radius is to the co-sine of the latitude; so is the number of miles in a degree of longitude, at the equator, to the number of miles in a degree of longitude, at such latitude.

The following table may be of use to the student, not only as giving the number of miles in a degree of longitude, at any distance from the equator, but for a comparison between geographical and statute miles. 69½ statute miles are taken as the measure of a degree at the equator. This is common reckoning, and will be found extremely near the truth.

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* Not a proper name, but the first star of the constellation.

TABLE OF GEOGRAPHICAL AND STATUTE MILES IN A DEGREE OF LONGITUDE AT EACH DEGREE OF LATITUDE.

Deg. lat.	Geogra'l mile	Statute miles.	Deg. lat.	Geogra'l miles.	Statute miles	Deg. lat.	Geogra'l miles	Statute miles.
1	59.99	69.49	31	51.43	59.57	61	29.09	33.69
2	59.96	69 46	32	50.88	58.94	62	28.17	32.63
3	59 92	69 40	33	50.32	58.29	63	27 24	31.55
4	59.85	69.33	34	49.74	57 62	64	26.30	30 47
5	59 77	69.24	35	49 15	56 93	65	25 36	29.37
6	59.67	69 12	36	48.54	56.23	66	24.40	28 27
7	59.55	68 98	37	47 92	55.51	67	23 44	27 16
8	59 42	68.82	38	47 28	54.77	68	22 48	26 04
9	59 26	68.64	39	46 63	54 01	69	21 50	24 91
10	59 09	68.44	40	45.96	53 24	70	20.52	23 77
11	58.90	68 22	41	45 28	52.45	71	19 53	22.63
12	58.69	67 98	42	44 59	51.65	72	18 54	21.48
13	58.46	67.72	43	43 88	50.83	73	17 54	20.32
14	58.22	67 43	44	43.16	49 99	74	16 54	19.16
15	57.96	67.13	45	42.43	49 14	75	15.53	17 99
16	57.68	66.81	46	41 68	48 28	76	14 52	16.81
17	57.38	66.46	47	40.92	47 40	77	13.50	15 63
18	57.06	66 10	48	40.15	46.50	78	12.47	14.45
19	56.73	65.71	49	39.36	45 60	79	11.45	13 26
20	56.38	65.31	50	38.57	44.67	80	10 42	12.07
21	56.01	64.88	51	37.76	43.74	81	9 39	10.87
22	55.63	64.44	52	36.94	42.79	82	8 35	9 67
23	55.23	63.98	53	36.11	41.83	83	7.31	8 47
24	54.81	63.49	54	35.27	40 85	84	6 27	7.26
25	54.38	62.99	55	34.41	39.86	85	5.23	6 06
26	53 93	62.47	56	33.55	38 86	86	4.19	4 85
27	53.46	61.92	57	32 68	37 85	87	3 14	3 64
28	52 98	61 36	58	31.80	36.83	88	2.09	2.43
29	52.48	60.79	59	30.90	35.80	89	1.05	1.21
30	51.96	60 19	60	30 00	34.75	90	0.00	0 00

CHAPTER XVII.

DEPRESSION OF THE HORIZON.

Connected with the finding of latitude and longitude, and thus, in some measure, with astronomy, is the *depression* or *dip* of the horizon. This is the angle of depression made by the visible horizon below the true sensible horizon at the place of observation. It arises from the elevation of the observer's eye. The higher the elevation of this, the more the visible horizon is depressed.

Let *A B D* be a great circle of the earth, *C* its centre, *E* the elevation of an observer's eye, *F G H* a part of the moon's orbit, *M* the moon, *E G* a line parallel to the sensible horizon; then will the angle *G E H* be the depression of the horizon to such an observer. The apparent altitude of the moon to an eye so elevated, would be the angle *M E H*; but her true altitude is the angle *M E G*. The depression of the horizon must, therefore, be subtracted from the observed altitude, in order to obtain the true altitude.

This correction applies in taking the altitude of the sun, or other heavenly body; and is the same, whatever be the distance or height of the object observed.

The depression of the horizon may be found for any elevation of the eye by trigonometry. For in the triangle *B C E*, the side *B C* is the semi-diameter of the earth, and the side *C E* is the sum of the height of the eye added to the semi-diameter of the earth, the angle *C B E* is a right angle. Hence, two sides and an angle are given to find the other angles. The angle *C E B* being found and subtracted from 90°, leaves the angle *G E H*, the depression of the horizon.

By the same figure, the depression of the horizon being know by observation or otherwise, the elevation of the observer's eye may be ascertained. Thus the height of a mountain may be found, when the visible horizon can be accurately taken; for the depression of the horizon is found by observation.

The following table, extracted for the purpose, shows the depression of the horizon at the specified heights.

Table of the depression or dip of the horizon.

Feet	′	″	Feet	′	″
1	0	59	26	5	1
2	1	24	27	5	7
3	1	42	28	5	13
4	1	58	29	5	18
5	2	12	30	5	24
6	2	25	40	6	14
7	2	36	50	6	58
8	2	47	60	7	37
9	2	57	70	8	14
10	3	7	80	8	48
11	3	16	90	9	20
12	3	25	100	9	51
13	3	33	200	13	55
14	3	41	300	17	4
15	3	49	400	19	42
16	3	56	500	22	1
17	4	4	600	24	8
18	4	11	700	26	3
19	4	17	800	27	51
20	4	24	900	29	35
21	4	31	1000	31	9
22	4	37	2000	44	3
23	4	43	3000	53	56
24	4	49	4000	62	18
25	4	55	5000	69	38

CHAPTER XVIII.

ARTIFICIAL GLOBES.

The problems solved by artificial globes, astronomical in their nature, form a proper appendage to astronomy.

A globe is a sphere or round body, of which every part of the surface is equally distant from the centre.

There are two kinds of artificial globes, *terrestrial* and *celestial.* On the terrestrial is represented the surface of the earth, diversified with land and water, and the principal divisions of each, forming a spherical map of the whole; on the celestial, the visible heavens, as distinguished into constellations, by the picture of the animal or other object of the constellation, and the principal stars, by which it is formed. A globe of either kind is placed upon a frame for convenient use. On each are represented the great imaginary circles of the sphere, the tropics and the polar circles.

CIRCLES ON THE TERRESTRIAL GLOBE.

The *equator*, about one eighth of an inch broad, is graduated for the longitude, 180° each way from the first meridian.

The *ecliptic*, about the same breadth, is inclined to the equator in an angle of 23° 28′, is divided into signs, and subdivided into degrees, beginning at the first of Aries.

The *meridians*, drawn with dark lines perpendicular to the equator, meet at the poles. 12 of these, 24 semicircles, form hour lines. One of the same passing through the equinoctial points, is the *equinoctial colure* ; another passing through the solstitial points, is the *solstitial colure*. Besides these, there is a *meridian of brass* encompassing the globe, half an inch or more broad, graduated on the eastern side.—on the upper semicircle of this, the graduation begins at the equator, and ends with 90° at each pole. On the lower semicircle it begins at the poles, and ends with 90° at the equator.

The *horizon* is represented by a *broad circle of wood*, divided at the four cardinal points, *north*, *south*, *east*, *west*. On this horizon next to the globe, are the amplitudes, a graduation of four nineties, beginning at the east and west points. Without these is a graduation of four nineties, beginning at the north and south points, for the azimuths.

Placed next to these are the 32 points of the compass.—Next are the figure, the name, and the character of the twelve signs ; then the graduation of each as in the ecliptic.

The exterior circle on the horizon represents the days of the months, so divided and adjusted to the signs, that each day of a month is placed at the degree of a sign in which the sun is at that time. Between the divisions of the days are small figures, showing how much the sun is fast or slow of the clock, marked —, when the sun is fast of the clock, and +, when it is slow.

Each tropic is represented on a terrestrial globe, by a single dark or coloured line, 23° 28 from the equator ; each polar circle in the same manner, 23° 28 from the pole.—Peculiar to this globe are parallels of latitude, drawn to each ten degrees.

At the north pole is an hour circle about two inches in diameter, divided into 24 parts, and numbered into two twelves, with a moveable index attached to the brazen meridian. At the south pole is a similar circle, and similarly divided and numbered, but without an index, time being computed from the brazen meridian.

There is some diversity in globes. The description answers to the one present with the author. Some globes have a quadrant of altitude, a thin strip of brass graduated into 90°, equal to 90° of a great circle on the globe.

The circles of an artificial globe are best learned by inspection, when the globe is at hand.

For using a globe stand on the east of it, facing the graduated side of the brazen meridian. This is the side to be used. To rectify the globe for the latitude of a place or any declination of the sun, is to elevate the nearest pole equal to the latitude of the place or the declination. When it is rectified for a place, such place brought to the brazen meridian is at the top or highest point of the globe. For instance, to rectify the globe for the latitude of Washington, elevate the north pole till 38° 53′ on the lower semicircle of the brazen meridian comes to the upper side of the wooden horizon; then Washington brought to the brazen meridian will be on the top of the globe.

When the globe is rectified for the sun's declination, the sun's place in the ecliptic, brought to the meridian, is on the top of the globe. Suppose you would rectify the globe for 20°, south declination of the sun, raise the south pole till 20°, on the brazen meridian below the pole, come against the upper side of the horizon. This will bring the sun's place, when at the meridian, to the most elevated point of the globe.

Great accuracy is not to be expected, in the solution of problems on artificial globes. The general knowledge to be obtained, however, is important.

PROBLEMS TO BE SOLVED BY THE TERRESTRIAL GLOBE.

PROBLEM I.

To find the Latitude and Longitude of a place.

Bring the place to the meridian.* Over it, on the meridian, is the latitude ; and at the intersection of the meridian and the equator, is the longitude.

What is the latitude and longitude of Jerusalem ?

Answer, about 32°N. 35°E.

What is the latitude and longitude of Canton, in China ?

23°N. 113°E.

PROBLEM II.

To find a place, the latitude and longitude of which are given.

Find the longitude on the equator, which bring to the meridian ; then directly under the latitude, found on the meridian, is the place.

What place is in 33° 51′S. 151° 16′E. ?

Port Jackson.

What place is in 12° 3′S. 76° 55′W. ?

Lima.

PROBLEM III.

To find the difference of latitude between two places.

Bring the places successively to the meridian, and note the latitude of each. If the latitudes be of the same name, both north, or both south, subtract the less from the greater, the remainder is the difference of latitude between them.—If the latitudes be of different names, one north and the other south, their sum is the difference sought.

What is the difference of latitude between Baltimore and Mexico ? 20°.

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* When a place is said to be brought to the meridian, the *brazen meridian* is intended.

Give the difference of latitude between Charleston S. C. and Buenos Ayres. 67° 30′.

The difference of latitude between Richmond, Virginia, and Lima is 49° 30′.

PROBLEM IV.

To find the difference of longitude between two places.

Find the longitude of each, as before directed, and, if the longitudes be of the same name, their difference is the difference sought. But if they be of different names, their sum, if less than 180°, is the result sought; if the sum be more than 180°, subtract it from 360°, the remainder is the difference of longitude between the places.

What is the difference of longitude between Portsmouth, N. H. and Cadiz? 64° 20′.

Required the difference of longitude between Paris and St. Louis. 92°.

Find the difference of longitude between Batavia and Cincinnati. 168°.

PROBLEM V.

To find the distance between two places on the globe.

With a pair of dividers, gently placed upon the globe,* take the extent between the places. Lay this extent on the equator and note the number of degrees. This number, multiplied by $69\frac{1}{2}$, gives the distance in statute miles. Multiplied by 60, it gives the distance in geographical miles.

When a globe has a quadrant of altitude, the number of degrees between places may be ascertained by laying it from one to another on the globe.

What is the distance from Boston to London?

About 3340 miles.

* Great care must be taken to apply the dividers laterally, and not point them against the globe. To avoid the danger of injury from dividers, the straight edge of a strip of paper may be used in taking the distance of objects on the globe.

Give the distance from New-York to St. Petersburg.
About 4300 miles.

Cape St. Rogue is distant from Cape Verd 1900 miles—1640 geo. miles.

Washington is distant from Gibraltar 3860 miles.

PROBLEM VI.

To find the Antoeci and Perioeci of any place.

Bring the place to the meridian, and observe the latitude; find the same latitude in the opposite hemisphere, under which latitude are the Antoeci.

With the given place at the meridian set the index at 12, turn the globe till the index points to the opposite 12, then under the meridian at the given latitude are the Perioeci.

The people in the southern part of Chili are Antoeci, and the Chinese Tartars, Perioeci to the inhabitants of New-England.

PROBLEM VII.

To find the Antipodes of any place.

Bring the place to the meridian, note the latitude, and set the index at 12. Turn the globe till the index points to the other 12, then in the opposite hemisphere, under the meridian at the same latitude are found the Antipodes, of the place.

Some of the New Zealanders are Antipodes to the inhabitants of Spain.

The inhabitants of the Society Islands are Antipodes to those in the interior of Africa.

PROBLEM VIII.

The hour of the day at any place being given, to find the time at any other place.

Bring the place where the hour is given to the meridian, and set the index at the hour ; turn the globe till the other place comes to the meridian, the index will show the hour required.

When it is 9 o'clock, A. M. at Boston, what is the time at Cairo in Egypt ?

3h. 47m. P. M.

When it is noon at Washington, what time is it at the Sandwich Islands ?

6h. 45m. A. M.

PROBLEM IX.

The hour of the day at any place being given, to find all those places, where it is any other given hour.

Bring the place to the meridian and set the index at the hour proposed for that place ; turn the globe till the index points to the other given hour ; the places sought will be under the meridian.

When the time is 4 o'clock, A. M. at New-York, where is it 11, A. M. ?

At St. Petersburg in Russia ; in the western part of the Caspian Sea ; the eastern part of the Mediterranean ; at Cairo in Egypt ; in the western part of Nubia, and a large western part of Central Africa.

At 11 o'clock, A. M. to the inhabitants of Washington, where is it midnight ?

In Siberia, Chinese Tartary, the eastern part of China, Borneo, and the western part of New Holland.

PROBLEM X.

To find the sun's place in the Ecliptic.

Find the day of the month on the horizon. Opposite to this in the adjacent sign is the degree of the sun's place.—Find the same sign and degree in the ecliptic and you have the sun's place.

On the 4th of July the sun's place in the ecliptic is 12° of Cancer.

On the 1st day of January the sun's place is 9° 30′ Capricorn.

PROBLEM XI.

To find the sun's declination on a given day.

Bring the sun's place in the ecliptic to the meridian. On the meridian directly over the sun's place is his declination.

The sun's declination on the first day of May, is 15° N.

The sun's declination on the last day of December is 23° S.

Besides this method of determining declinations, there is an analemma on the globe, the graduated segment of a circle, about nine tenths of an inch broad, on which the declination for each day is set against the days of the months.

PROBLEM XII.

To find at what places the sun is vertical on a given day.

Find and note the degree of the sun's declination. Turn the globe round and to all places coming under that degree the sun is vertical.

On the 28th of August the sun is vertical to the northern part of the Colombian Republic, to Guinea, Abyssinia, the southern part of Hindostan, and Malacca.

On the 20th of January the sun is vertical to Buenos Ayres, Brazil, South Africa, Madagascar, New Holland, and many islands in the south sea.

PROBLEM XIII.

To find where the sun is vertical at any given hour.

Bring the place where the hour is given to the meridian, and set the index at the given hour. Turn the globe westward for the forenoon, eastward for the afternoon, till the index points to 12 ; under the degree of the sun's declination is the place sought.

When it is 11 o'clock, A. M. at Washington, on the 10th of April, where is the sun vertical ?

To the Colombian Republic, near the mouth of the river Orinoco.

When it is 10 o'clock, P. M. at New York, on the 10th of December, the sun is vertical in the interior of New Holland.

PROBLEM XIV.

To find at any place and time of year what hour the sun rises and sets ; also the length of the day and night.

Rectify the globe for the latitude of the place. Find the sun's place in the ecliptic, bring it to the meridian, and set the index at 12. Turn the globe eastward, till the sun's place comes to the edge of the horizon, the index will point to the time of the sun's rising. Turn the sun's place to the western edge of the horizon, the index will show the time of his setting.

Double the time of the sun's setting is the length of the day ; double the time of his rising is the length of the night.

At Boston on the 1st of June, the sun rises about 4h. 30m. sets about 7h. 30m. The length of the day is 15 hours the night 9 hours.

PROBLEM XV.

To find the length of the longest and shortest day at any place below the polar circles.

Rectify the globe for the latitude of the place. For northern latitudes bring the first degree of Cancer to the meridian, and set the index at 12. Turn the same first degree of Cancer to the western edge of the horizon ; the index will shew the time of the sun's setting, which doubled gives the length of the longest day. This subtracted from 24 hours, leaves the length of the shortest day.

For southern latitudes bring the first degree of Capricorn to the meridian, and proceed as before.

The longest and shortest days are equal to the longest and shortest nights, no allowance being made for refraction and different magnitudes of the sun and earth.

The longest day at Concord, N. H. is	15h. 12m.
The shortest is	8h. 48m.
The longest day at Archangel is	20h. 30m.
The shortest is	3h. 30m.

PROBLEM XVI.

To find at any given time where the sun is rising and where setting ; where it is noon and where midnight.

Rectify the globe for the sun's declination and bring the place where the sun is vertical at the hour to the meridian. To places at the western edge of the horizon the sun then appears rising ; to places at the eastern edge, setting. At the meridian above the horizon, it is noon ; at the meridian below, midnight.

When the time is January 1st, 0h. 30m. P. M. at Washington, the sun is rising at the western Sandwich Islands, a little to the west of the Friendly Islands, and New Zealand. It is noon in Hudson's Bay, Upper Canada, Michigan territoky, Indiana, Kentucky, Tennessee, western Georgia, Gulf of Mexico, and Guatimala. The sun is setting at Cape Farewell, in Africa near the mouth of the Gambia and Liberia, and the Cape of Good Hope.

PROBLEM XVII.

To find by the globe and the table of longitude how far any place moves in an hour by the earth's rotation on its axis.

By the globe find the latitude of the place, and by the tables, the number of miles in a degree. Multiply these by 15, the product is the result required.

Washington moves about 812 statute miles in an hour.

Caraccas moves 1025 statute, 885 geographical miles per hour.

Nova Zembla moves 217 statute, 187 geographical miles per hour.

THE CELESTIAL GLOBE.

The celestial globe, besides the circles common to this and the terrestrial globe, has secondaries drawn perpendicular to the ecliptic at every ten degrees, meeting at the poles of the ecliptic. It has also a representation of the zodiac. The great circles are here graduated as on the terrestrial globe. The degrees are numbered in the same manner, except on the equator, which, beginning at the first degree of Aries, is numbered for Right Ascension eastward round the globe.

PROBLEMS SOLVED BY THE CELESTIAL GLOBE.

PROBLEM I.

To find the right ascension of the sun or a star.

Bring the sun's place, or the star to the meridian. On the equator at its intersection with the meridian is the degree of right ascension.

The sun's right ascension on the fourth day of July is 102°

The right ascension of Regulus is 149° 30′

PROBLEM II.

To find the declination of a star.

Bring the star to the meridian. Directly over it on the meridian is the declination.

The declination of Arcturus is 20° 20′N.

The declination of Sirius is 16° 30′S.

The sun's declination is found on this as on the terrestrial globe.

PROBLEM III.

To find the longitude of the sun or a star.

The sun's longitude is his distance from the first of Aries. This is the same as his place in the ecliptic.

To find the longitude of a star, lay the edge of the quadrant of altitude, or the straight edge of a strip of paper, from the nearest pole of the ecliptic by the star to the ecliptic. At its intersection with the ecliptic is the longitude. Or, where a perpendicular line from the star strikes the ecliptic is the longitude of the star.

The longitude of the sun on the 4th of March is 11^s 13°.

The longitude of Aldebaran is 2^s 7°.

PROBLEM IV.

To find the latitude of a star.

Take with the dividers, a strip of paper, or thread, the nearest distance of the star from the ecliptic. Lay the extent on the equator from the first of Aries, and you have the degrees of the star's latitude.

The latitude of Alioth is 54° 30′N.

The latitude of Fomalhaut is 21° 6′S.

When a globe has a quadrant of altitude, the latitude of a star may be taken by applying the graduated edge of that from the ecliptic to the star, without recourse to the equator.

PROBLEM V.

The right ascension and declination of a star being given, to find the star on the globe.

Bring the right ascension to the meridian, under which at the declination will be found the star.

What star is 112° right ascension, 5° 40′ N. declination ?

Procyon.

What star is 198° 45′ right ascension, and 10°S. declination ?

Spica.

PROBLEM VI.

The latitude and longitude of a star being given, to find the star on the globe.

Find the sign and degree of the longitude in the ecliptic. Take with dividers from the first of Aries on the equator a number of degrees equal to the star's latitude. Lay the extent north or south, as the star's latitude may be, perpendicularly from the ecliptic at the star's longitude, and you will find the star.

What star is in 13° Capricorn and 62 N. latitude ?

Vega.

What star is in 27° 20′ Gemini and 16° 10′ S. latitude ?

Betelguese.

PROBLEM VII.

The time of year at any place being given, to find at what hour any star will rise, be in the meridian, and set.

Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian, and set the index at 12. Turn the globe till the star comes to the eastern edge of the horizon, the index will show the time of its rising. Bring it to the meridian, the index will show the time. Turn it to the western edge of the horizon, the index will show the time of its setting.

On the 20th of January, at Boston, Sirius rises 5h. 45m. P. M. is on the meridian at 10h. 30m. P. M. and sets at 3h. 15m. A. M. of the 21st.

At New-York, on the 1st of May, Arcturus rises at 4h. 23m. P. M. is on the meridian at 11h. 32m. P. M., and sets at 6h. 40m. of the following day.

PROBLEM VIII.

To find the altitude of a star at any given time.

Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian and set the index at 12. Turn the globe till the index points to the time proposed. Then with the quadrant of altitude, or dividers, take the nearest distance of the star from the horizon; the number of degrees on the quadrant, or in the extent of the dividers applied to the equator, shows the altitude.

What is the altitude of Procyon, as seen at Washington, February 1st, at 7 o'clock, P. M.? 32° 40′.

What is the altitude of Vega as seen from New-Haven, September 26, at 2 o'clock A. M.?

9° 30′ above the western horizon.

PROBLEM IX.

Having the altitude of a star given, to know the time of night.

Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian, and set the index at 12. Turn the globe till the star comes to the altitude proposed; the index will point to the hour required.

What is the time of night at Philadelphia, on the 20th of

October, when the largest star of the Pleiades is 15° above the eastern horizon ? 8h P. M.

What is the time of night at Boston, on the last day of August, when Arcturus is 10° above the western horizon ? 9h. 45m P. M.

This and the preceding problem may be applied to finding the altitude of the sun, and the time of day, by setting the index at 12, when the sun's place is brought to the meridian, turning the globe, and taking the altitude from the height of his place and the time from the altitude, as in the case of a star.

PROBLEM X.

The latitude of a place being given, to place the globe so as to represent the appearance of the heavens at any hour proposed.

Rectify the globe for the latitude of the place. Bring the sun's place in the ecliptic to the meridian and set the index at 12. Turn the globe eastward for the forenoon, westward for the afternoon, till the index points to the given hour.—The globe will then represent the appearance of the heavens at the time proposed

Represent the appearance of the heavens at Washington, March 20th, at 7 o'clock, P. M.

Arcturus is rising at 25° north of east, Procyon has nearly arrived at the meridian ; Sirius is a little past ; the bright constellation, Orion, a little farther past. Nearly in the same rank is Capella to the north. In front of all these and a little farther in western declination, are Aldebaran, the Hyades, and Pleiades.

Represent the appearance of the heavens at Boston, September the 23rd, 7h. 40m. P. M.

Fomalhaut is a little above the eastern horizon. Altair is on the meridian ; Vega is a little declined from the zenith. The constellations, Corona, Borealis, and Bootes, with bright Arcturus, fast declining, adorn the western hemisphere.

When the latitude and apparent time, at different places, are the same, the appearance of the heavens is the same, notwithstanding a difference of longitude; or the same with a very trifling variation. Lisbon, in Portugal, is nearly in the same parallel of latitude, as Washington City. At 10 o'clock in the evening, therefore, the appearance of the heavens is very nearly the same at Lisbon, as at 10 in the evening observed from Washington. The general appearance is altered but little by a small difference of latitude.—The distance from Boston to Washington will not make a great alteration.

A familiar use of the globes is recommended to the student. It will greatly improve his knowledge of geography and astronomy. It will make him more interested in contemplating the objects of the visible heavens, a delightful and innocent amusement for the evening, or the most lonely hours of night. What is much more; by observation on the celestial canopy, he must be irresistibly led from the greatness of the scenery to the contemplation of the immensity and infinite goodness of the Great Author.

ASTRONOMICAL TABLES.

TABLE I.—Mean new moon in March, with the mean anomalies of the sun and moon, and the sun's mean distance from the moon's ascending node for the 19th century.

Years of Christ	Mean new moon in March.				Sun's anomaly.				Moon's anomaly.				Sun's mean distance from node.			
	D.	H.	M	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
1800	24	19	14	35	8	23	19	55	10	7	52	36	11	3	58	23
1801	14	4	3	12	8	12	35	46	8	17	40	41	11	12	1	10
1802	3	12	51	48	8	1	51	37	6	27	28	46	11	20	3	58
1803	22	10	24	28	8	20	13	48	6	3	5	52	0	28	46	59
1804	10	19	13	4	8	9	29	39	4	12	53	57	1	6	49	46
1805	29	16	45	44	8	27	51	49	3	18	31	2	2	15	32	47
1806	19	1	34	21	8	17	7	40	1	28	19	7	2	23	35	35
1807	8	10	22	57	8	6	23	31	0	8	7	12	3	1	38	22
1808	26	7	55	37	8	24	45	42	11	13	44	18	4	10	21	23
1809	15	16	44	13	8	14	1	33	9	23	32	23	4	18	24	10
1810	5	1	32	50	8	3	17	24	8	3	20	28	4	26	26	58
1811	23	23	5	30	8	21	39	35	7	8	57	34	6	5	9	59
1812	12	7	54	6	8	10	55	26	5	18	45	39	6	13	12	46
1813	1	16	42	43	8	0	11	17	3	28	33	44	6	21	15	33
1814	20	14	15	23	8	18	33	27	3	4	10	49	7	29	58	35
1815	9	23	3	59	8	7	49	18	1	13	58	54	8	8	1	22
1816	27	20	36	39	8	26	11	29	0	19	36	0	9	16	44	23
1817	17	5	25	15	8	15	27	20	10	29	24	5	9	24	47	10
1818	6	14	13	52	8	4	43	11	9	9	12	10	10	2	49	58
1819	25	11	46	32	8	23	5	21	8	14	49	15	11	11	32	59
1820	13	20	35	8	8	12	21	12	6	24	37	21	11	19	35	46
1821	3	5	23	45	8	1	37	4	5	4	25	26	11	27	38	33
1822	22	2	56	24	8	19	59	14	4	10	2	31	1	6	21	35
1823	11	11	45	1	8	9	15	5	2	19	50	36	1	14	24	22
1824	29	9	17	41	8	27	37	16	1	25	27	42	2	23	7	23
1325	18	18	6	17	8	16	53	7	0	5	15	47	3	1	10	10
1826	8	2	54	54	8	6	8	58	10	15	3	52	3	9	12	58
1827	27	0	27	33	8	24	31	8	9	20	40	57	4	17	55	59
1828	15	9	16	10	8	13	46	59	8	0	29	2	4	25	58	46
1829	4	18	4	47	8	3	2	50	6	10	17	8	5	4	1	33
1830	23	15	37	26	8	21	25	1	5	15	54	13	6	12	44	35
1831	13	0	26	3	8	10	40	52	3	25	42	18	6	20	47	22
1832	1	9	14	39	7	29	56	43	2	5	30	23	6	28	50	9
1833	20	6	47	19	8	18	18	54	1	11	7	29	8	7	33	10
1834	9	15	35	56	8	7	34	45	11	20	55	34	8	15	35	58
1835	28	13	8	35	8	25	56	55	10	26	32	39	9	24	18	59
1836	16	21	57	12	8	15	12	46	9	6	20	44	10	2	21	46
1837	6	6	45	49	8	4	28	37	7	16	8	49	10	10	24	33
1838	25	4	18	28	8	22	50	48	6	21	45	55	11	19	7	35
1839	14	13	7	5	8	12	6	39	5	1	34	0	11	27	10	22

Years of Christ	Mean new moon in March				Sun's anomaly				Moon's anomaly.				Sun's distance from node.			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
1840	2	21	55	41	8	1	22	30	3	11	22	5	0	5	13	9
1841	21	19	28	21	8	19	44	40	2	16	59	11	1	13	56	10
1842	11	4	16	58	8	9	0	32	0	26	47	16	1	21	58	58
1843	30	1	49	37	8	27	22	12	0	2	24	21	3	0	41	59
1844	18	10	38	14	8	16	38	33	10	12	12	26	3	8	44	46
1845	7	19	26	50	8	5	54	24	8	22	0	31	3	16	47	33
1846	26	16	59	30	8	24	16	35	7	27	37	37	4	25	30	35
1847	16	1	48	7	8	13	32	26	6	7	25	42	5	3	33	22
1848	4	10	36	43	8	2	48	17	4	17	13	47	5	11	36	9
1849	23	8	9	23	8	21	10	27	3	22	50	53	6	20	19	10
1850	12	16	58	0	8	10	26	18	2	2	38	58	6	28	21	58
1851	2	1	46	36	7	29	42	10	0	12	27	3	7	6	24	45
1852	19	23	19	16	8	18	4	20	11	18	4	8	8	15	7	46
1853	9	8	7	52	8	7	20	11	9	27	52	13	8	23	10	33
1854	28	5	40	32	8	25	42	21	9	3	29	19	10	1	53	35
1855	17	14	29	9	8	14	58	13	7	13	17	24	10	9	56	22
1856	5	23	17	45	8	4	14	4	5	23	5	29	10	17	59	8
1857	24	20	50	25	8	22	36	14	4	28	42	34	11	26	42	19
1858	14	5	39	1	8	11	52	5	3	8	30	40	0	4	44	58
1859	3	14	27	38	8	1	7	56	1	18	18	45	0	12	47	45
1860	21	12	0	18	8	19	30	7	0	23	55	50	1	21	30	46
1861	10	20	48	54	8	8	45	58	11	3	43	55	1	29	33	33
1862	29	18	21	34	8	27	8	8	10	9	21	1	3	8	16	35
1863	19	3	10	10	8	16	23	59	8	19	9	6	3	16	19	22
1864	7	11	58	47	8	5	39	51	6	28	57	11	3	24	22	9
1865	26	9	31	27	8	24	2	1	6	4	34	16	5	3	5	10
1866	15	18	20	3	8	13	17	52	4	14	22	21	5	11	7	58
1867	5	3	8	40	8	2	33	43	2	24	10	27	5	19	10	45
1868	23	0	41	20	8	20	55	54	1	29	47	32	6	27	53	46
1869	12	9	29	56	8	10	11	45	0	9	35	37	7	5	56	33
1870	1	18	18	33	7	29	27	36	10	19	23	42	7	13	59	21
1871	20	15	51	12	8	17	49	46	9	25	0	48	8	22	42	22
1872	9	0	39	49	8	7	5	37	8	4	48	53	9	0	45	9
1873	27	22	12	29	8	25	27	48	7	10	25	58	10	9	28	10
1874	17	7	1	5	8	14	43	39	5	20	14	3	10	17	30	58
1875	6	15	49	42	8	3	59	30	4	0	2	8	10	25	33	45
1876	24	13	22	21	8	22	21	40	3	5	39	14	0	4	16	46
1877	13	22	10	58	8	11	37	32	1	15	27	19	0	12	19	33
1878	3	6	59	35	8	0	53	23	11	25	15	24	0	20	22	21
1879	22	4	32	14	8	19	15	33	11	0	52	30	1	29	5	22
1880	10	13	20	51	8	8	31	24	9	10	40	35	2	7	8	9
1881	29	10	53	31	8	26	53	35	8	16	17	40	3	15	51	10
1882	18	19	42	7	8	16	9	26	6	26	5	45	3	23	53	58
1883	8	4	30	44	8	5	25	17	5	5	53	50	4	1	56	45
1884	26	2	3	23	8	23	47	27	4	11	30	56	5	10	39	46

TABLE I.—Continued.

Years of Christ	Mean new moon in March.				Sun's anomaly.				Moon's anomaly.				Sun's mean distance from node			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
1885	15	10	52	0	8	13	3	18	2	21	19	1	5	18	42	33
1886	4	19	40	37	8	2	19	10	1	1	7	6	5	26	45	21
1887	23	17	13	16	8	20	41	20	0	6	44	12	7	5	28	22
1888	12	2	1	53	8	9	57	11	10	16	32	17	7	13	31	9
1889	1	10	50	29	7	29	13	2	8	26	20	22	7	21	33	56
1890	20	8	23	9	8	17	35	13	8	1	57	27	9	0	16	58
1891	9	17	11	46	8	6	51	4	6	11	45	32	9	8	19	45
1892	27	14	44	25	8	25	13	14	5	17	22	38	10	17	2	46
1893	16	23	33	2	8	14	29	5	3	27	10	43	10	25	5	33
1894	6	8	21	38	8	3	44	56	2	6	58	48	11	3	8	21
1895	25	5	54	18	8	22	7	7	1	12	35	53	0	11	51	22
1896	13	14	42	55	8	11	22	58	11	22	23	58	0	19	54	9
1897	2	23	31	31	8	0	38	49	10	2	12	4	0	27	56	56
1898	21	21	4	11	8	19	0	59	9	7	49	9	2	6	39	58
1899	11	5	52	47	8	8	16	51	7	17	37	14	2	14	42	45
1900	30	3	25	27	8	26	39	1	6	23	14	20	3	23	25	46

TABLE II.

The mean anomalies of the sun and moon and the sun's mean distance from the moon's ascending node, for 13½ mean lunations.

No.	Mean lunations.				Sun's anomaly.				Moon's anomaly.				Sun's distance from node			
	D.	H.	M.	S.	S.	°	′	″	S.	°	′	″	S.	°	′	″
1	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
2	59	1	28	6	1	28	12	39	1	21	38	1	2	1	20	28
3	88	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
4	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
5	147	15	40	15	4	25	31	36	4	9	5	2	5	3	21	10
6	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
7	206	17	8	21	6	23	44	15	6	0	43	3	7	4	41	38
8	236	5	52	24	7	22	50	34	6	26	32	3	8	5	21	52
9	265	18	36	27	8	21	56	53	7	22	21	4	9	6	2	5
10	295	7	20	30	9	21	3	13	8	18	10	4	10	6	42	19
11	324	20	4	34	10	20	9	32	9	13	59	5	11	7	22	33
12	354	8	48	37	11	19	15	51	10	9	48	5	0	8	2	47
13	383	21	32	40	0	18	22	10	11	5	37	6	1	8	43	1
½	14	18	22	2	0	14	33	10	6	12	54	30	0	15	20	7

TABLE III.

The difference of new moon in March, with the corresponding anomalies and distance of the sun from the node for complete centuries of Julian years.																
Julian years.	Mean new moon in March				Sun's anomaly.				Moon's anomaly.				Sun from node.			
	D	H.	M.	S.	S.	°	′	″	S	°	′	″	S.	°	′	″
100	4	8	10	52	0	3	19	6	8	15	21	44	4	19	27	23
200	8	16	21	44	0	6	38	12	5	0	43	27	9	8	54	46
300	13	0	32	36	0	9	57	18	1	16	5	11	1	28	22	9
400	17	8	43	29	0	13	16	24	10	1	26	55	6	17	49	32
500	21	16	54	21	0	16	35	30	6	16	48	38	11	7	16	55
600	26	1	5	13	0	19	54	36	3	2	10	22	3	26	44	19
700	30	9	16	5	0	23	13	42	11	17	32	6	8	16	11	42
800	5	4	42	54	11	27	26	29	7	7	4	49	0	4	58	51
900	9	12	53	46	0	0	45	35	3	22	26	33	4	24	26	14
1000	13	21	4	39	0	4	4	41	0	7	48	16	9	13	53	37
2000	27	18	9	17	0	8	9	21	0	15	36	32	6	27	47	14
3000	12	2	29	53	11	13	7	43	11	27	35	48	3	11	0	37
4000	25	23	34	31	11	17	12	23	0	5	24	4	0	24	54	14
5000	10	7	55	7	10	22	10	45	11	17	23	20	9	8	7	37
10000	20	15	50	14	9	14	21	30	11	4	46	40	6	16	15	14

TABLE IV.

Days of the year, reckoned from the beginning of March.												
Days.	Mar	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov	Dec.	Jan.	Feb.
1	1	32	62	93	123	154	185	215	246	276	307	338
2	2	33	63	94	124	155	186	216	247	277	308	339
3	3	34	64	95	125	156	187	217	248	278	309	340
4	4	35	65	86	126	157	188	218	249	279	310	341
5	5	36	66	97	127	158	189	219	250	280	311	342
6	6	37	67	98	128	159	190	220	251	281	312	343
7	7	38	68	99	129	160	191	221	252	282	313	344
8	8	39	69	100	130	161	192	222	253	283	314	345
9	9	40	70	101	131	162	193	223	254	284	315	346
10	10	41	71	102	132	163	194	224	255	285	316	347
11	11	42	72	103	133	164	195	225	256	286	317	348
12	12	43	73	104	134	165	196	226	257	287	318	349
13	13	44	74	105	135	166	197	227	258	288	319	350
14	14	45	75	106	136	167	198	228	259	289	320	351
15	15	46	76	107	137	168	199	229	260	290	321	352

TABLE IV.—Continued.

Days.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
16	16	47	77	108	138	169	200	230	261	291	322	353
17	17	48	78	109	139	170	201	231	262	292	323	354
18	18	49	79	110	140	171	202	232	263	293	324	355
19	19	50	80	111	141	172	203	233	264	294	325	356
20	20	51	81	112	142	173	204	234	265	295	326	357
21	21	52	82	113	143	174	205	235	266	296	327	358
22	22	53	83	114	144	175	206	236	267	297	328	359
23	23	54	84	115	145	176	207	237	268	298	329	360
24	24	55	85	116	146	177	208	238	269	299	330	361
25	25	56	86	117	147	178	209	239	270	300	331	362
26	26	57	87	118	148	179	210	240	271	301	332	363
27	27	58	88	119	149	180	211	241	272	302	333	364
28	28	59	89	120	150	181	212	242	273	303	334	365
29	29	60	90	121	151	182	213	243	274	304	335	366
30	30	61	91	122	152	183	214	244	275	305	336	
31	31		92		153	184		245		306	337	

TABLE V.

The first equation of the mean to the true syzygy.

Argument. The sun's mean anomaly.

Subtract.

Deg.	S. 0 H.	M.	S.	1 H.	M.	S.	2 H.	M.	S.	3 H.	M.	S.	4 H.	M.	S.	5 H.	M	S. S.	Deg.
0	0	0	0	2	3	12	3	35	0	4	10	53	3	39	30	2	7	45	30
1	0	4	18	2	6	55	3	37	10	4	10	57	3	37	19	2	3	55	29
2	0	8	35	2	10	36	3	39	18	4	10	55	3	35	6	2	0	1	28
3	0	12	51	2	14	14	3	41	23	4	10	49	3	32	50	1	56	5	27
4	0	17	8	2	17	52	3	43	26	4	10	39	3	30	30	1	52	6	26
5	0	21	24	2	21	27	3	45	25	4	10	24	3	28	5	1	48	4	25
6	0	25	39	2	25	9	3	47	19	4	10	4	3	25	35	1	41	1	24
7	0	28	55	2	28	29	3	49	7	4	9	39	3	23	0	1	39	56	23
8	0	34	11	2	31	57	3	50	50	4	9	10	3	20	20	1	35	49	22
9	0	38	26	2	35	22	3	52	29	4	8	37	3	17	35	1	31	41	21
10	0	42	39	2	38	44	3	54	4	4	7	59	3	14	49	1	27	31	20
11	0	46	52	2	42	3	3	55	35	4	7	16	3	11	59	1	23	19	19
12	0	51	4	2	45	18	3	57	2	4	6	29	3	9	6	1	19	5	18
13	0	55	17	2	48	30	3	58	27	4	5	37	3	6	10	1	14	49	17
14	0	59	27	2	51	40	3	59	49	4	4	41	3	3	10	1	10	33	16
15	1	3	36	2	54	48	4	1	7	4	3	40	3	0	7	1	6	15	15

TABLE V.—Continued.

Deg.	S. 0 H.	M.	S.	1 H.	M.	S.	2 H.	M.	S.	3 H.	M.	S.	4 H.	M.	S.	5 S. H.	M.	S.	Deg.
16	1	7	45	2	57	53	4	2	18	4	2	35	2	57	0	1	1	56	14
17	1	11	53	3	0	54	4	3	23	4	1	26	2	53	49	0	57	36	13
18	1	16	0	3	3	51	4	4	22	4	0	12	2	50	36	0	53	15	12
19	1	20	6	3	6	45	4	5	18	3	58	52	2	47	18	0	48	52	11
20	1	24	10	3	9	36	4	6	10	3	57	27	2	43	57	0	44	28	10
1	1	28	12	3	12	24	4	6	58	3	55	59	2	40	33	0	40	2	9
22	1	32	12	3	15	9	4	7	41	3	54	26	2	37	6	0	35	36	8
23	1	36	10	3	17	51	4	8	21	3	52	49	2	33	35	0	31	10	7
24	1	40	6	3	20	30	4	8	57	3	51	9	2	30	2	0	26	44	6
25	1	44	1	3	23	5	4	9	29	3	49	26	2	26	26	0	22	17	5
26	1	47	54	3	25	36	4	9	55	3	47	38	2	22	47	0	17	50	4
27	1	51	46	3	28	3	4	10	16	3	45	44	2	19	5	0	13	23	3
28	1	55	37	3	30	26	4	10	33	3	43	45	2	15	20	0	8	56	2
29	1	59	26	3	32	45	4	10	45	3	41	40	2	11	35	0	4	29	1
30	2	3	12	3	35	0	4	10	53	3	39	30	2	7	45	0	0	0	0
Deg.	S. 11			10			9			8			7			6 S.			Deg.
	Add.																		

TABLE VI.

Equation of the moon's mean anomaly.

Argument. Sun's mean anomaly.

Subtract.

Deg.	S. 0 °	′	″	1 °	′	″	2 °	′	″	3 °	′	″	4 °	′	″	5 S. °	′	″	Deg.
0	0	0	0	0	46	45	1	21	32	1	35	1	1	23	4	0	48	19	30
1	0	1	37	0	48	10	1	22	21	1	35	2	1	22	14	0	46	51	29
2	0	3	13	0	49	34	1	23	10	1	35	1	1	21	24	0	45	23	28
3	0	4	52	0	50	53	1	23	57	1	35	0	1	20	32	0	43	54	27
4	0	6	28	0	52	19	1	24	41	1	34	57	1	19	38	0	42	24	26
5	0	8	6	0	53	40	1	25	24	1	34	50	1	18	42	0	40	53	25
6	0	9	42	0	55	0	1	26	6	1	34	43	1	17	45	0	39	21	24
7	0	11	20	0	56	21	1	26	48	1	34	33	1	16	48	0	37	49	23
8	0	12	56	0	57	38	1	27	28	1	34	22	1	15	47	0	36	15	22
9	0	14	33	0	58	56	1	28	6	1	34	9	1	14	44	0	34	40	21
10	0	16	10	1	0	13	1	28	43	1	33	53	1	13	41	0	33	5	20
11	0	17	47	1	1	29	1	29	17	1	33	37	1	12	37	0	31	31	19
12	0	19	23	1	2	43	1	29	51	1	33	20	1	11	33	0	29	54	18
13	0	20	59	1	3	56	1	30	22	1	33	0	1	10	26	0	28	18	17
14	0	22	35	1	5	8	1	30	50	1	32	38	1	9	17	0	26	40	16
15	0	24	10	1	6	18	1	31	19	1	32	14	1	8	8	0	25	3	15

TABLE VI.—Continued.

Deg.	S. 0 °	′	″	1 °	′	″	2 °	′	″	3 °	′	″	4 °	′	″	5 S. °	′	″	Deg.
16	0	25	45	1	7	27	1	31	45	1	31	50	1	6	58	0	23	23	14
17	0	27	19	1	8	36	1	32	12	1	31	23	1	5	46	0	21	45	13
18	0	28	52	1	9	42	1	32	34	1	30	55	1	4	32	0	20	7	12
19	0	30	25	1	10	49	1	32	57	1	30	25	1	3	19	0	18	28	11
20	0	31	57	1	11	54	1	33	17	1	29	51	1	2	1	0	16	48	10
21	0	33	29	1	12	58	1	33	36	1	29	20	1	0	45	0	15	8	9
22	0	35	2	1	14	1	1	33	52	1	28	45	0	59	26	0	13	28	8
23	0	36	32	1	15	1	1	34	6	1	28	9	0	58	7	0	11	48	7
24	0	38	1	1	16	0	1	34	18	1	27	30	0	56	45	0	10	7	6
25	0	39	29	1	16	59	1	34	30	1	26	50	0	55	23	0	8	20	5
26	0	40	59	1	17	57	1	34	40	1	26	27	0	54	1	0	6	44	4
27	0	42	26	1	18	52	1	34	48	1	25	5	0	52	37	0	5	3	3
28	0	43	54	1	19	47	1	34	54	1	24	39	0	51	12	0	3	21	2
29	0	45	19	1	20	40	1	34	58	1	23	52	0	49	45	0	1	40	1
30	0	46	45	1	21	32	1	35	1	1	23	4	0	48	19	0	0	0	0
Deg.	S. 11			10			9			8			7			6 S.			Deg.
	Add.																		

TABLE VII.

The second equation of the mean to the true syzygy.

Argument. Moon's equated anomaly.

Add.

Deg.	S. 0 H.	M.	S.	1 H.	M.	S.	2 H.	M.	S.	3 H.	M.	S.	4 H.	M.	S.	5 S. H.	M.	S.	Deg.
0	0	0	0	5	12	48	8	47	8	9	46	44	8	8	59	4	34	33	30
1	0	10	58	5	21	56	8	51	45	9	46	3	8	3	12	4	26	1	29
2	0	21	56	5	30	57	8	56	10	9	45	12	7	57	23	4	17	25	28
3	0	32	54	5	39	51	9	0	25	9	44	11	7	51	33	4	8	47	27
4	0	43	52	5	48	37	9	4	31	9	42	59	7	45	46	4	0	7	26
5	0	54	50	5	57	17	9	8	25	9	41	36	7	39	46	3	51	23	25
6	1	5	48	6	5	51	9	12	9	9	40	3	7	33	36	3	42	32	24
7	1	16	46	6	14	19	9	15	43	9	38	19	7	27	22	3	33	38	23
8	1	27	44	6	22	41	9	19	5	9	36	24	7	21	2	3	24	42	22
9	1	38	40	6	30	57	9	22	14	9	34	18	7	14	30	3	15	44	21
10	1	49	33	6	39	4	9	25	12	9	32	1	7	7	50	3	6	45	20
11	2	0	23	6	47	0	9	27	58	9	29	33	7	1	2	2	57	43	19
12	2	11	10	6	54	46	9	30	32	9	26	54	6	54	8	2	48	39	18
13	2	21	54	7	2	24	9	32	58	9	24	4	6	47	9	2	39	34	17
14	2	32	34	7	9	52	9	35	12	9	21	3	6	40	6	2	30	28	16
15	2	43	9	7	17	9	9	37	14	9	17	51	6	32	56	2	21	19	15

TABLE VII.—Continued.

Deg.	S. 0 H.	M.	S.	1 H.	M.	S.	2 H.	M.	S.	3 H.	M.	S.	4 H.	M.	S.	5 S. H.	M.	S.	Deg.
16	2	53	38	7	24	19	9	39	8	9	14	28	6	25	40	2	12	8	14
17	3	4	3	7	31	18	9	40	51	9	10	54	6	18	18	2	2	53	13
18	3	14	24	7	38	9	9	42	21	9	7	9	6	10	49	1	53	36	12
19	3	24	42	7	44	51	9	43	42	9	3	13	6	3	16	1	44	16	11
20	3	34	58	7	51	24	9	44	53	8	59	6	5	55	38	1	34	54	10
21	3	45	11	7	57	45	9	45	52	8	54	50	5	47	54	1	25	31	9
22	3	55	21	8	3	56	9	46	38	8	50	24	5	40	4	1	16	7	8
23	4	5	26	8	9	57	9	47	13	8	45	48	5	32	9	1	6	41	7
24	4	15	26	8	15	46	9	47	36	8	41	2	5	24	9	0	57	13	6
25	4	25	20	8	21	24	9	47	49	8	36	6	5	16	5	0	47	44	5
26	4	35	6	8	26	53	9	47	54	8	31	0	5	7	56	0	38	13	4
27	4	44	42	8	32	11	9	47	46	8	25	44	4	59	42	0	28	41	3
28	4	54	11	8	37	19	9	47	33	8	20	18	4	51	15	0	19	8	2
29	5	3	33	8	42	18	9	47	14	8	14	33	4	43	2	0	9	34	1
30	5	12	48	8	47	3	9	46	44	8	8	59	4	34	33	0	0	0	0
	S. 11			10			9			8			7			6 S.			
	Subtract.																		

TABLE VIII.

The third equation of the mean to the true syzygy.

Argument. The sun's anomaly—Moon's.

Deg.	Signs. 0— 6+ M.	S.	Signs. 1— 7+ M.	S.	Signs. 2— 8+ M.	S.	Deg.
0	0	0	2	22	4	12	30
1	0	5	2	26	4	15	29
2	0	10	2	30	4	18	28
3	0	15	2	34	4	21	27
4	0	20	2	38	4	24	26
5	0	25	2	42	4	27	25
6	0	30	2	46	4	30	24
7	0	35	2	50	4	32	23
8	0	40	2	54	4	34	22
9	0	45	2	58	4	36	21
10	0	50	3	2	4	38	20

TABLE VIII.—Continued.

Deg.	Signs. 0— 6+		Signs. 1— 7+		Signs. 2— 8+		Deg.
	M.	S.	M.	S.	M.	S.	
11	0	55	3	6	4	40	19
12	1	0	3	10	4	42	18
13	1	5	3	14	4	44	17
14	1	10	3	18	4	46	16
15	1	15	3	22	4	48	15
16	1	20	3	26	4	50	14
17	1	25	3	30	4	51	13
18	1	30	3	34	4	52	12
19	1	35	3	38	4	53	11
20	1	40	3	42	4	54	10
21	1	45	3	45	4	55	9
22	1	49	3	48	4	56	8
23	1	52	3	51	4	57	7
24	1	56	3	54	4	57	6
25	2	0	3	57	4	57	5
26	2	4	4	0	4	58	4
27	2	9	4	3	4	58	3
28	2	13	4	6	4	58	2
29	2	18	4	9	4	58	1
30	2	22	4	12	4	58	0
Deg.	S. 5— 11+		4— 10+		3— S. 9+		Deg.

TABLE IX.

The fourth equation of the mean to the true syzygy.

Argument. The sun's distance from node.

Add.

Deg.	S. 0 6		1 7		2 S. 8		Deg.
	M.	S.	M.	S.	M.	S.	
0	0	0	1	22	1	22	30
1	0	4	1	23	1	21	29
2	0	7	1	24	1	20	28
3	0	10	1	25	1	18	27
4	0	13	1	26	1	16	26
5	0	16	1	27	1	14	25

TABLE IX.—Continued.

Deg.	S. 0 6		1 7		2 S. 8		Deg.
	M.	S.	M.	S.	M.	S.	
6	0	20	1	28	1	12	24
7	0	23	1	29	1	10	23
8	0	26	1	30	1	8	22
9	0	29	1	31	1	6	21
10	0	32	1	32	1	3	20
11	0	35	1	33	1	0	19
12	0	38	1	33	0	57	18
13	0	41	1	34	0	54	17
14	0	44	1	34	0	51	16
15	0	47	1	34	0	49	15
16	0	50	1	34	0	45	14
17	0	52	1	34	0	41	13
18	0	54	1	34	0	37	12
19	0	57	1	33	0	34	11
20	1	0	1	33	0	31	10
21	1	2	1	32	0	28	9
22	1	5	1	31	0	25	8
23	1	8	1	30	0	22	7
24	1	10	1	29	0	19	6
25	1	12	1	28	0	16	5
26	1	14	1	27	0	13	4
27	1	16	1	26	0	10	3
28	1	18	1	25	0	6	2
29	1	20	1	24	0	3	1
30	1	22	1	22	0	0	0
Deg.	S. 5 11		4 10		3 9		Deg.

Subtract.

TABLE X.

The sun's longitude and anomaly for the 19th century of the Christian era.

Years.	Longitude.				Anomaly.				Years.	Longitude.				Anomaly.			
	S.	°	′	″	S.	°	′	″		S.	°	′	″	S.	°	′	″
1800	9	10	7	13	6	0	44	12	1831	9	9	37	4	5	29	42	0
1801	9	9	52	54	6	0	28	51	B 1832	9	10	21	53	6	0	25	46
1802	9	9	38	34	6	0	13	29	1833	9	10	7	33	6	0	10	25
1803	9	9	24	14	5	29	58	7	1834	9	9	53	13	5	29	55	3
B 1804	9	10	9	3	6	0	41	54	1835	9	9	38	54	5	29	39	42
1805	9	9	54	44	6	0	26	32	B 1836	9	10	23	43	6	0	23	28
1806	9	9	40	24	6	0	11	11	1837	9	10	9	23	6	0	8	7
1807	9	9	26	4	5	29	55	49	1838	9	9	55	3	5	29	52	45
B 1808	9	10	10	53	6	0	39	36	1839	9	9	40	44	5	29	37	23
1809	9	9	56	33	6	0	24	14	B 1840	9	10	25	33	6	0	21	10
1810	9	9	42	14	6	0	8	53	1841	9	10	11	13	6	0	5	48
1811	9	9	27	54	5	29	53	31	1842	9	9	56	53	5	29	50	27
B 1812	9	10	12	43	6	0	37	18	1843	9	9	42	34	5	29	35	5
1813	9	9	58	23	6	0	21	56	B 1844	9	10	27	22	6	0	18	52
1814	9	9	44	4	6	0	6	34	1845	9	10	13	3	6	0	3	30
1815	9	9	29	44	5	29	51	13	1846	9	9	58	43	5	29	48	8
B 1816	9	10	14	33	6	0	34	59	1847	9	9	44	24	5	29	32	47
1817	9	10	0	13	6	0	19	38	B 1848	9	10	29	12	6	0	16	33
1818	9	9	45	54	6	0	4	16	1849	9	10	14	53	6	0	1	12
1819	9	9	31	34	5	29	48	55	1850	9	10	0	33	5	29	45	50
B 1820	9	10	16	23	6	0	32	41	1851	9	9	46	14	5	29	30	29
1821	9	10	2	3	6	0	17	19	B 1852	9	10	31	2	6	0	14	15
1822	9	9	47	44	6	0	1	58	1853	9	10	16	43	5	29	58	54
1823	9	9	33	24	5	29	46	36	1854	9	10	2	23	5	29	43	32
B 1824	9	10	18	13	6	0	30	23	1855	9	9	48	3	5	29	28	10
1825	9	10	3	53	6	0	15	1	1856	9	10	32	52	6	0	11	57
1826	9	9	49	34	5	29	59	40	1857	9	10	18	33	5	29	56	35
1827	9	9	35	14	5	29	54	18	1858	9	10	4	13	5	29	41	14
B 1828	9	10	20	3	6	0	28	5	1859	9	9	49	53	5	29	25	52
1829	9	10	5	43	6	0	12	43	B 1860	9	10	34	42	6	0	9	39
1830	9	9	51	24	5	29	57	21	1861	9	10	20	23	5	29	54	17

TABLE X.—Continued.

Years.	Longitude. S	°	′	″	Anomaly. S	°	′	″	Years.	Longitude. S.	°	′	″	Anomaly. S.	°	′	″
1862	9	10	6	3	5	29	38	55	1882	9	10	15	13	5	29	27	24
1863	9	9	51	43	5	29	23	34	1883	9	10	0	53	5	29	12	3
B 1864	9	10	36	32	6	0	7	20	B 1884	9	10	45	42	5	29	55	49
1865	9	10	22	12	5	29	51	59	1885	9	10	31	22	5	29	40	28
1866	9	10	7	53	5	29	36	37	1886	9	10	17	3	5	29	25	6
1867	9	9	53	33	5	29	21	16	1887	9	10	2	43	5	29	9	44
B 1868	9	10	38	22	6	0	5	2	B 1888	9	10	47	32	5	29	53	31
1869	9	10	24	2	5	29	49	41	1899	9	10	33	12	5	29	38	9
1870	9	10	9	43	5	29	34	19	1890	9	10	18	52	5	29	22	48
1871	9	9	55	23	5	29	18	57	1891	9	10	4	33	5	29	7	26
B 1872	9	10	40	12	6	0	2	44	B 1892	9	10	49	22	5	29	51	13
1873	9	10	25	52	5	29	47	22	1893	9	10	35	2	5	29	35	51
1874	9	10	11	33	5	29	32	1	1894	9	10	20	42	5	29	20	30
1875	9	9	57	13	5	29	16	39	1895	9	10	6	23	5	29	5	8
B 1876	9	10	42	2	6	0	0	26	B 1896	9	10	51	12	5	29	48	55
1877	9	10	27	42	5	29	45	4	1897	9	10	36	52	5	29	33	33
1878	9	10	13	23	5	29	29	43	1898	9	10	22	32	5	29	18	11
1879	9	9	59	3	5	29	14	21	1899	9	10	8	13	5	29	2	50
B 1880	9	10	43	52	5	29	58	7	1900	9	9	53	53	5	28	47	28
1881	9	10	29	32	5	29	42	46									

The sun's longitude and anomaly in Julian years.

Years	Longitude. S	°	′	″	Anomaly. S.	°	′	″
1	11	29	45	40	11	29	44	38
2	11	29	31	21	11	29	29	17
3	11	29	17	1	11	29	13	55
B 4	0	0	1	50	11	29	57	42
5	11	29	47	30	11	29	42	20
6	11	29	33	11	11	29	26	59
7	11	29	18	51	11	29	11	37
B 8	0	0	3	40	11	29	55	24
9	11	29	49	20	11	29	40	2
10	11	29	35	1	11	29	24	40
B 20	0	0	9	10	11	29	48	29
30	11	29	44	10	11	29	13	9
B 40	0	0	18	19	11	29	36	58

Years.		Longitude.				Anomaly.			
		S.	°	′	″	S	°	′	″
	50	11	29	53	20	11	29	1	38
B	60	0	0	27	29	11	29	25	26
	70	0	0	2	30	11	28	50	7
B	80	0	0	36	39	11	29	13	55
	90	0	0	11	39	11	28	38	36
B	100	0	0	45	48	11	29	2	24
B	200	0	1	31	36	11	28	4	48
B	300	0	2	17	25	11	27	7	12
B	400	0	3	3	13	11	26	9	36
B	500	0	3	49	1	11	25	12	0
B	600	0	4	34	49	11	24	14	24
B	700	0	5	20	38	11	23	16	48
B	800	0	6	6	26	11	22	19	12
B	900	0	6	52	14	11	21	21	36
B	1000	0	7	38	2	11	20	24	0
B	2000	0	15	16	5	11	10	48	0
B	3000	0	22	54	7	11	1	12	0
B	4000	1	0	32	10	10	21	36	0
B	5000	1	8	10	12	10	12	0	0
B	10000	2	16	20	24	8	24	0	0

The sun's mean motion in longitude and anomaly from the commencement of the year to the beginning of each month.

Months.	Longitude.				Anomaly.			
	S.	°	′	″	S.	°	′	″
Jan.	0	0	0	0	0	0	0	0
Feb.	1	0	33	18	1	0	33	13
March	1	28	9	11	1	28	9	1
April	2	28	42	30	2	28	42	14
May	3	28	16	40	3	28	16	19
June	4	28	49	58	4	28	49	32
July	5	28	24	8	5	28	23	37
Aug.	6	28	57	26	6	28	56	50
Sept.	7	29	30	44	7	29	30	3
Oct.	8	29	4	54	8	29	4	8
Nov.	9	29	38	12	9	29	37	21
Dec.	10	29	12	22	10	29	11	21

The sun's mean motion in longitude and anomaly in days.

Days.	Longitude.				Anomaly.			
	s	°	′	″	s.	°	′	″
1	0	0	59	8	0	0	59	8
2	0	1	58	17	0	1	58	16
3	0	2	57	25	0	2	57	24
4	0	3	56	33	0	3	56	33
5	0	4	55	42	0	4	55	41
6	0	5	54	50	0	5	54	49
7	0	6	53	58	0	6	53	57
8	0	7	53	7	0	7	53	5
9	0	8	52	15	0	8	52	13
10	0	9	51	23	0	9	51	22
11	0	10	50	32	0	10	50	30
12	0	11	49	40	0	11	49	38
13	0	12	48	48	0	12	48	46
14	0	13	47	57	0	13	47	54
15	0	14	47	5	0	14	47	2
16	0	15	46	13	0	15	46	11
17	0	16	45	22	0	16	45	19
18	0	17	44	30	0	17	44	27
19	0	18	43	38	0	18	43	35
20	0	19	42	47	0	19	42	43
21	0	20	41	55	0	20	41	51
22	0	21	41	3	0	21	41	0
23	0	22	40	12	0	22	40	8
24	0	23	39	20	0	23	39	16
25	0	24	38	28	0	24	38	24
26	0	25	37	37	0	25	37	32
27	0	26	36	45	0	26	36	40
28	0	27	35	53	0	27	35	48
29	0	28	35	2	0	28	34	57
30	0	29	34	10	0	29	34	5
31	1	0	33	18	1	0	33	13

The sun's mean motion in longitude, anomaly, and distance from the node for hours, minutes and seconds.

	Longitude and anomaly.				Distance from node.				Longitude and anomaly				Distance from node.		
H	°	'	"	'''	°	'	"	H.	°	'	"	'''	°	'	"
M	'	"	'''	''''	'	"	'''	M.	'	"	'''	''''	'	"	'''
S	"	'''	''''	'''''	"	'''	''''	S.	"	'''	''''	'''''	"	'''	''''
1	0	2	27	51	0	2	36	31	1	16	23	15	1	20	29
2	0	4	55	42	0	5	12	32	1	18	51	6	1	23	5
3	0	7	23	32	0	7	47	33	1	21	18	57	1	25	41
4	0	9	51	23	0	10	23	34	1	23	46	48	1	28	17
5	0	12	19	14	0	12	59	35	1	26	14	39	1	30	53
6	0	14	47	5	0	15	35	36	1	28	42	30	1	33	28
7	0	17	14	56	0	18	11	37	1	31	10	20	1	36	4
8	0	19	42	47	0	20	46	38	1	33	38	11	1	38	40
9	0	22	10	37	0	23	22	39	1	36	6	2	1	41	16
10	0	24	38	28	0	25	58	40	1	38	33	53	1	43	52
11	0	27	6	19	0	28	34	41	1	41	1	44	1	46	27
12	0	29	34	10	0	31	9	42	1	43	29	34	1	49	3
13	0	32	2	1	0	33	45	43	1	45	57	25	1	51	39
14	0	34	29	51	0	36	21	44	1	48	25	16	1	54	15
15	0	36	57	42	0	38	57	45	1	50	53	7	1	56	51
16	0	39	25	33	0	41	33	46	1	53	20	58	1	59	26
17	0	41	53	24	0	44	8	47	1	55	48	49	2	2	2
18	0	44	21	15	0	46	44	48	1	58	16	39	2	4	38
19	0	46	49	6	0	49	20	49	2	0	44	30	2	7	14
20	0	49	16	56	0	51	56	50	2	3	12	21	2	9	50
21	0	51	44	47	0	54	32	51	2	5	40	12	2	12	25
22	0	54	12	38	0	57	7	52	2	8	8	3	2	15	1
23	0	56	40	29	0	59	43	53	2	10	35	53	2	17	37
24	0	59	8	20	1	2	19	54	2	13	3	44	2	20	13
25	1	1	36	11	1	4	55	55	2	15	31	35	2	22	48
26	1	4	4	1	1	7	31	56	2	17	59	26	2	25	24
27	1	6	31	52	1	10	6	57	2	20	27	17	2	28	0
28	1	8	59	43	1	12	42	58	2	22	55	8	2	30	36
29	1	11	27	34	1	15	18	59	2	25	22	58	2	33	12
30	1	13	55	25	1	17	54	60	2	27	50	49	2	35	47

TABLE XI.

Equation of the sun's centre or the difference between his mean and true place.

Argument. The sun's mean anomaly.

Subtract.

Deg.	S. 0			1			2			3			4			5 S.			Deg.
	°	'	"	°	'	"	°	'	"	°	'	"	°	'	"	°	'	"	
0	0	0	0	0	56	47	1	39	6	1	55	37	1	41	12	0	58	53	30
1	0	1	59	0	58	30	1	40	7	1	55	39	1	40	12	0	57	7	29
2	0	3	57	1	0	12	1	41	6	1	55	38	1	39	10	0	55	19	28
3	0	5	56	1	1	53	1	42	3	1	55	36	1	38	6	0	53	30	27
4	0	7	54	1	3	33	1	42	59	1	55	31	1	37	0	0	51	40	26
5	0	9	52	1	5	12	1	43	52	1	55	24	1	35	52	0	49	49	25
6	0	11	50	1	6	50	1	44	44	1	55	15	1	34	43	0	47	57	24
7	0	13	48	1	8	27	1	45	34	1	55	3	1	33	32	0	46	5	23
8	0	15	46	1	10	2	1	46	22	1	54	50	1	32	19	0	44	11	22
9	0	17	43	1	11	36	1	47	8	1	54	35	1	31	4	0	42	16	21
10	0	19	40	1	13	9	1	47	53	1	54	17	1	29	47	0	40	21	20
11	0	21	37	1	14	41	1	48	35	1	53	57	1	28	29	0	38	25	19
12	0	23	33	1	16	11	1	49	15	1	53	36	1	27	9	0	36	28	18
13	0	25	29	1	17	40	1	49	54	1	53	12	1	25	48	0	34	30	17
14	0	27	25	1	19	8	1	50	30	1	52	46	1	24	25	0	32	32	16
15	0	29	20	1	20	34	1	51	5	1	52	18	1	23	0	0	30	33	15
16	0	31	15	1	21	59	1	51	37	1	51	48	1	21	34	0	28	33	14
17	0	33	9	1	23	22	1	52	8	1	51	15	1	20	6	0	26	33	13
18	0	35	2	1	24	44	1	52	36	1	50	41	1	18	36	0	24	33	12
19	0	36	55	1	26	5	1	53	3	1	50	5	1	17	5	0	22	32	11
20	0	38	47	1	27	24	1	53	27	1	49	26	1	15	33	0	20	30	10
21	0	40	39	1	28	41	1	53	50	1	48	46	1	13	59	0	18	28	9
22	0	42	30	1	29	57	1	54	10	1	48	3	1	12	24	0	16	26	8
23	0	44	20	1	31	11	1	54	28	1	47	19	1	10	47	0	14	24	7
24	0	46	9	1	32	24	1	54	44	1	46	32	1	9	9	0	12	21	6
25	0	47	57	1	33	35	1	54	58	1	45	44	1	7	29	0	10	18	5
26	0	49	45	1	34	45	1	55	10	1	44	53	1	5	49	0	8	14	4
27	0	51	32	1	35	53	1	55	20	1	44	1	1	4	7	0	6	11	3
28	0	53	18	1	36	59	1	55	23	1	43	7	1	2	24	0	4	7	2
29	0	55	3	1	38	3	1	55	34	1	42	10	1	0	39	0	2	4	1
30	0	56	47	1	39	6	1	55	37	1	41	12	0	58	53	0	0	0	0
Deg.	S. 11			10			9			8			7			6			Deg.
	Add.																		

TABLE XII.

The sun's declination for every degree of his longitude.

Argument. The sun's longitude.

Deg.	S. 0 / 6			1 / 7			2 / 8 S.			Deg.
	°	′	″	°	′	″	°	′	″	
0	0	0	0	11	29	5	20	10	25	30
1	0	23	53	11	50	6	20	22	57	29
2	0	47	47	12	10	56	20	35	7	28
3	1	11	39	12	31	34	20	46	55	27
4	1	35	30	12	51	59	20	58	20	26
5	1	59	20	13	12	12	21	9	21	25
6	2	23	8	13	32	12	21	19	59	24
7	2	46	54	13	51	58	21	30	13	23
8	3	10	37	14	11	30	21	40	3	22
9	3	34	17	14	30	48	21	49	29	21
10	3	57	54	14	49	52	21	58	30	20
11	4	21	27	15	8	40	22	7	6	19
12	4	44	57	15	27	13	22	15	17	18
13	5	8	22	15	45	30	22	23	3	17
14	5	31	42	16	3	31	22	30	24	16
15	5	54	57	16	21	16	22	37	18	15
16	6	18	6	16	38	44	22	43	47	14
17	6	41	9	16	55	55	22	49	50	13
18	7	4	6	17	12	48	22	55	27	12
19	7	26	57	17	29	23	23	0	38	11
20	7	49	41	17	45	40	23	5	22	10
21	8	12	17	18	1	38	23	9	39	9
22	8	34	45	18	17	18	23	13	29	8
23	8	57	5	18	32	38	23	16	53	7
24	9	19	17	18	47	38	23	19	50	6
25	9	41	19	19	2	18	23	22	20	5
26	10	3	12	19	16	37	23	24	22	4
27	10	24	56	19	30	35	23	25	57	3
28	10	46	30	19	44	13	23	27	5	2
29	11	7	53	19	57	30	23	27	46	1
30	11	29	5	20	10	25	23	28	0	0
Deg.	S. 11 / 5			10 / 4			9 / 3 S.			Deg.

TABLE XIII.

Equation of the sun's mean distance from the node

Argument. The sun's mean anomaly.

Subtract.

Deg.	S. 0 °	'	1 °	'	2 °	'	3 °	'	4 °	'	5 S. °	'	Deg.
0	0	0	1	2	1	47	2	5	1	50	1	4	30
1	0	2	1	4	1	48	2	5	1	48	1	2	29
2	0	4	1	6	1	49	2	5	1	47	1	0	28
3	0	6	1	8	1	50	2	5	1	46	0	58	27
4	0	9	1	10	1	51	2	5	1	45	0	56	26
5	0	11	1	12	1	52	2	5	1	44	0	54	25
6	0	13	1	14	1	53	2	5	1	43	0	52	24
7	0	15	1	16	1	54	2	4	1	41	0	50	23
8	0	17	1	17	1	55	2	4	1	40	0	48	22
9	0	19	1	18	1	56	2	4	1	39	0	46	21
10	0	21	1	19	1	57	2	4	1	37	0	44	20
11	0	23	1	21	1	58	2	3	1	36	0	42	19
12	0	25	1	22	1	58	2	3	1	34	0	40	18
13	0	28	1	24	1	59	2	3	1	33	0	37	17
14	0	30	1	26	2	0	2	2	1	31	0	35	16
15	0	32	1	27	2	0	2	2	1	30	0	33	15
16	0	34	1	28	2	1	2	1	1	28	0	31	14
17	0	36	1	30	2	1	2	1	1	27	0	29	13
18	0	38	1	31	2	2	2	0	1	25	0	27	12
19	0	40	1	34	2	2	2	0	1	24	0	24	11
20	0	42	1	35	2	3	1	59	1	23	0	22	10
21	0	44	1	36	2	3	1	59	1	21	0	20	9
22	0	46	1	37	2	4	1	58	1	19	0	18	8
23	0	48	1	39	2	4	1	57	1	17	0	16	7
24	0	50	1	40	2	4	1	56	1	15	0	13	6
25	0	52	1	41	2	4	1	55	1	13	0	11	5
26	0	54	1	43	2	5	1	54	1	11	0	9	4
27	0	56	1	44	2	5	1	53	1	9	0	7	3
28	0	58	1	45	2	5	1	52	1	8	0	5	2
29	1	0	1	46	2	5	1	51	1	6	0	3	1
30	1	2	1	47	2	5	1	50	1	4	0	0	0
	S. 11		10		9		8		7		6 S.		

Add.

TABLE XIV.

The moon's latitude in eclipses.

Argument.—The moon's equated distance from node

0 signs north ascending.

6 signs south descending.

°	°	'	"	°
0	0	0	0	30
1	0	5	15	29
2	0	10	30	28
3	0	15	45	26
4	0	20	59	26
5	0	26	13	25
6	0	31	26	24
7	0	36	39	23
8	0	41	51	22
9	0	47	2	21
10	0	52	13	20
11	0	57	23	19
12	1	2	31	18
13	1	7	38	17
14	1	12	44	16
15	1	17	49	15
16	1	22	52	14
17	1	27	53	13
18	1	32	52	12
19	1	37	49	11

5 S. north descending.

11 S. south ascending.

TABLE XV.

The moon's horizontal parallax; the semi-diameters, and true horary motions of the sun and moon to every sixth degree of their mean anomalies.

Anomaly of sun & moon.		Moon's horizontal parallax.		Sun's semi-diameter.		Moon's semi-diameter.		Moon's horary motion.		Sun's horary motion.		Anomaly of sun and moon.	
S.	°	'	"	'	"	'	"	'	"	'	"	S.	°
0	0	54	29	15	50	14	54	30	10	2	23	12	0
	6	54	31	15	50	14	55	30	12	2	23		24
	12	54	34	15	50	14	56	30	15	2	23		18
	18	54	40	15	51	14	57	30	19	2	23		12
	24	54	47	15	51	14	58	30	26	2	23		6
1	0	54	56	15	52	14	59	30	34	2	24	11	0
	6	55	6	15	53	15	1	30	44	2	24		24
	12	55	17	15	54	15	4	30	55	2	24		18
	18	55	29	15	55	15	8	31	9	2	24		12
	24	55	42	15	56	15	12	31	23	2	25		6
2	0	55	56	15	58	15	17	31	40	2	25	10	0
	6	56	12	15	59	15	22	31	56	2	26		24
	12	56	29	16	1	15	26	32	17	2	27		18
	18	56	48	16	2	15	30	32	39	2	27		12
	24	57	8	16	4	15	36	33	1	2	28		6
3	0	57	30	16	6	15	41	33	23	2	28	9	0
	6	57	52	16	8	15	46	33	47	2	29		24
	12	58	12	16	10	15	52	34	11	2	29		18
	18	58	31	16	11	15	58	34	34	2	29		12
	24	58	49	16	13	16	3	34	58	2	30		6
4	0	59	6	16	14	16	9	35	22	2	30	8	0
	6	59	21	16	15	16	14	35	45	2	31		24
	12	59	35	16	17	16	19	36	0	2	31		18
	18	59	48	16	19	16	24	36	20	2	32		12
	24	60	0	16	20	16	28	36	40	2	32		6
5	0	60	11	16	21	16	31	37	0	2	32	7	0
	6	60	21	16	21	16	32	37	10	2	33		24
	12	60	30	16	22	16	37	37	19	2	33		18
	18	60	38	16	22	16	38	37	28	2	33		12
	24	60	45	16	23	16	39	37	36	2	33		6
6	0	60	45	16	23	16	39	37	40	2	33	6	0

TABLE XVI.

Longitude on the earth changed into solar time.

°	H.	M.
′	M.	S.
″	S.	T.
1	0	4
2	0	8
3	0	12
4	0	16
5	0	20
6	0	24
7	0	28
8	0	32
9	0	36
10	0	40
11	0	44
12	0	48
13	0	52
14	0	56
15	1	0
16	1	4
17	1	8
18	1	12
19	1	16
20	1	20
30	2	0
40	2	40
50	3	20
60	4	0
70	4	40
80	5	20
90	6	0
100	6	40

TABLE XVII.

Angle of the moon's visible path with the ecliptic.

Argument. The sun's distance from the node.

0 Signs. 6

Horary motion of the moon from the sun.

	27′	28′	29′	30′	31′	32′	33′	34′	35′	36′	
°	° ″	° ″	° ″	° ″	° ″	° ″	° ″	° ″	° ″	° ″	°
0	5 47	5 46	5 45	5 44	5 43	5 42	5 41	5 41	5 40	5 39	30
3	5 46	5 45	5 44	5 43	5 42	5 42	5 41	5 40	5 40	5 39	27
6	5 45	5 44	5 43	5 42	5 41	5 40	5 39	5 39	5 38	5 38	24
9	5 42	5 41	5 40	5 39	5 39	5 38	5 37	5 37	5 36	5 35	21
12	5 39	5 38	5 37	5 36	5 35	5 35	5 34	5 33	5 33	5 32	18
15	5 35	5 34	5 33	5 32	5 31	5 31	5 30	5 29	5 29	5 28	15

11 Signs 5.

TABLE XVIII.

Equation of time. The sun faster or slower than the clock.

Bissextile.

Days.	Jan M.	Jan S.	Feb. M.	Feb. S.	March. M.	March. S.	April. M.	April. S.	May. M.	May. S.	June. M.	June. S.
	Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.	
1	4	8	14	4	12	27	3	38	3	13	2	28
2	4	36	14	11	12	14	3	20	3	20	2	18
3	5	4	14	17	12	1	3	2	3	27	2	9
4	5	31	14	23	11	47	2	44	3	33	1	59
5	5	58	14	28	11	32	2	26	3	38	1	49
6	6	25	14	32	11	18	2	9	3	43	1	38
7	6	50	14	35	11	3	1	51	3	47	1	27
8	7	15	14	37	10	47	1	34	3	51	1	15
9	7	40	14	38	10	31	1	17	3	53	1	3
10	8	5	14	39	10	15	1	1	3	55	0	51
11	8	29	14	39	9	58	0	45	3	57	0	39
12	8	52	14	38	9	41	0	29	3	59	0	27
13	9	15	14	37	9	24	0	14	4	0	0	15
14	9	36	14	34	9	7	0 *	2	4	0	0	2
15	9	57	14	31	8	50	0	16	3	59	0 *	11
							Sun fast of clock.				Sun slow of clock.	
16	10	18	14	27	8	32	0	31	3	58	0	24
17	10	38	14	23	8	14	0	45	3	56	0	36
18	10	57	14	18	7	56	0	59	3	53	0	49
19	11	16	14	12	7	38	1	12	3	50	1	2
20	11	34	14	6	7	20	1	25	3	47	1	16
21	11	50	13	58	7	2	1	37	3	43	1	29
22	12	6	13	50	6	43	1	48	3	39	1	42
23	12	22	13	42	6	25	1	59	3	34	1	55
24	12	37	13	33	6	6	2	10	3	29	2	8
25	12	51	13	24	5	48	2	21	3	23	2	20
26	13	4	13	14	5	29	2	31	3	16	2	33
27	13	16	13	3	5	11	2	41	3	9	2	45
28	13	27	12	51	4	52	2	50	3	1	2	57
29	13	38	12	39	4	33	2	58	2	53	3	9
30	13	48			4	15	3	6	2	45	3	20
31	13	57			3	56			2	38		

Equation of time. The sun faster or slower than the clock.

Bissextile.

July.		Aug.		Sept.		Oct.		Nov.		Dec.	
Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock. * Sun slow clock	
M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
3	31	5	50	0	34	10	42	16	15	10	12
3	42	5	46	0	53	11	1	16	15	9	48
3	53	5	41	1	12	11	19	16	15	9	24
4	3	5	35	1	32	11	37	16	13	8	59
4	14	5	29	1	52	11	55	16	10	8	33
4	24	5	22	2	12	12	12	16	6	8	7
4	33	5	14	2	32	12	28	16	2	7	41
4	42	5	6	2	52	12	44	15	57	7	14
4	51	4	58	3	13	12	59	15	51	6	46
4	58	4	49	3	34	13	15	15	44	6	19
5	7	4	39	3	54	13	30	15	36	5	51
5	14	4	29	4	15	13	44	15	27	5	22
5	21	4	19	4	36	13	58	15	18	4	53
5	27	4	7	4	57	14	11	15	8	4	24
5	33	3	55	5	18	14	23	14	56	3	54
5	39	3	43	5	39	14	35	14	44	3	25
5	44	3	30	6	0	14	47	14	31	2	55
5	49	3	17	6	20	14	56	14	18	2	25
5	53	3	3	6	41	15	7	14	4	1	55
5	57	2	49	7	2	15	16	13	49	1	25
5	59	2	35	7	23	15	25	13	32	0	55
6	1	2	20	7	44	15	33	13	15	0	25
6	3	2	4	8	4	15	40	12	58	0 *	5
6	4	1	48	8	24	15	47	12	40	0	35
6	4	1	31	8	45	15	53	12	21	1	5
6	4	1	14	9	5	15	59	12	1	1	35
6	4	0	57	9	25	16	4	11	41	2	4
6	2	0	40	9	45	16	8	11	19	2	33
6	0	0	22	10	4	16	10	10	57	3	2
5	57	0	4	10	23	16	12	10	35	3	31
5	54	0 *	15			16	14				0

Equation of time. The sun faster or slower than the clock. First after bissextile.																		
Days.	Jan. M.		S.	Feb. M.		S.	March. M.		S.	April. M.		S.	May. M.		S.	June. M.		S.
1	4	Sun slow	29	14	Sun slow	10	12	Sun slow	30	3	Sun slow	43	3	Sun fast	12	2	Sun fast	31
2	4		57	14		17	12		17	3		25	3		19	2		22
3	5		25	14		22	12		4	3		6	3		26	2		12
4	5		52	14		27	11		51	2		48	3		32	2		2
5	6		19	14		32	11		37	2		31	3		37	1		52
6	6	of clock.	44	14	of clock.	35	11	of clock.	22	2	of clock.	13	3	of clock.	42	1	of clock.	41
7	7		9	14		37	11		7	1		56	3		46	1		31
8	7		35	14		39	10		52	1		39	3		50	1		19
9	7		59	14		40	10		36	1		22	3		53	1		7
10	8		23	14		40	10		20	1		5	3		55	0		55
11	8		46	14		39	10		3	0		49	3		57	0		43
12	9		9	14		38	9		46	0		33	3		59	0		31
13	9		31	14		35	9		29	0		17	4		0	0		19
14	9		52	14		32	9		12	0		2	4		0	0		7
15	10		13	14		28	8		54	0	*	13	4		0	0	*	6
16	10		33	14		24	8		37	0	Sun fast	28	3		59	0	Sun slow	19
17	10		52	14		19	8		19	0		42	3		58	0		32
18	11		11	14		14	8		1	0		56	3		55	0		45
19	11		29	14		8	7		43	1		9	3		52	0		58
20	11		46	14		0	7		25	1		22	3		49	1		11
21	12		2	13		52	7		6	1	of clock.	35	3		46	1	of clock.	24
22	12		18	13		44	6		48	1		47	3		41	1		37
23	12		33	13		35	6		29	1		58	3		37	1		50
24	12		47	13		26	6		11	2		9	3		31	2		3
25	13		1	13		16	5		52	2		19	3		25	2		16
26	13		13	13		6	5		34	2		30	3		19	2		28
27	13		24	12		54	5		15	2		39	3		12	2		41
28	13		35	12		42	4		56	2		48	3		4	2		53
29	13		45				4		38	2		57	2		56	3		5
30	13		54				4		19	3		5	2		48	3		17
31	14		3				4		1				2		40			

Equation of time. The sun faster or slower than the clock.											
First after bissextile.											
July.		Aug.		Sept.		Oct.		Nov.		Dec.	
Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock.	
M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M.	S.
3	28	5	51	0	28	10	36	16	14	10	17
3	39	5	47	0	47	10	55	16	14	9	54
3	50	5	42	1	6	11	13	16	13	9	30
4	0	5	37	1	26	11	31	16	12	9	5
4	11	5	31	1	46	11	49	16	9	8	39
4	21	5	24	2	6	12	6	16	6	8	13
4	30	5	16	2	26	12	22	16	2	7	47
4	39	5	8	2	46	12	38	15	58	7	20
4	48	5	0	3	7	12	54	15	52	6	53
4	57	4	51	3	27	13	10	15	45	6	25
5	4	4	42	3	48	13	25	15	37	5	57
5	11	4	32	4	9	13	39	15	29	5	29
5	18	4	22	4	30	13	53	15	20	5	0
5	25	4	10	4	51	14	6	15	10	4	31
5	31	3	58	5	12	14	19	14	59	4	2
5	37	3	46	5	33	14	31	14	47	3	32
5	42	3	34	5	54	14	42	14	34	3	3
5	47	3	21	6	14	14	53	14	21	2	33
5	51	3	7	6	35	15	3	14	7	2	3
5	55	2	53	6	56	15	13	13	52	1	33
5	58	2	39	7	17	15	22	13	36	1	3
6	0	2	24	7	37	15	30	13	19	0	32
6	2	2	9	7	58	15	37	13	2	0	2
6	3	1	53	8	18	15	44	12	44	0	* 28
6	4	1	36	8	39	15	51	12	25	0	58
6	4	1	19	8	59	15	56	12	5	1	28
6	4	1	2	9	19	16	1	11	45	1	57
6	3	0	45	9	38	16	5	11	24	2	26
6	1	0	27	9	58	16	9	11	2	2	56
5	58	0	9	10	17	16	11	10	40	3	25
5	55	0	* 9			16	13			3	53

(Dec., from the * onward: Sun slow of clock.)

Equation of time. The sun faster or slower than the clock.

Second after bissextile.

Days.	Jan. M.	Jan. S.	Feb. M.	Feb. S.	March. M.	March. S.	April. M.	April. S.	May. M.	May. S.	June. M.	June. S.
	Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.	
1	4	21	14	7	12	32	3	46	3	11	2	34
2	4	49	14	14	12	20	3	28	3	18	2	25
3	5	17	14	20	12	6	3	10	3	25	2	15
4	5	44	14	25	11	53	2	52	3	31	2	6
5	6	11	14	29	11	39	2	34	3	37	1	55
6	6	37	14	33	11	24	2	16	3	42	1	45
7	7	2	14	35	11	10	1	59	3	46	1	34
8	7	27	14	37	10	55	1	42	3	50	1	22
9	7	52	14	39	10	39	1	25	3	53	1	10
10	8	16	14	39	10	23	1	9	3	55	0	58
11	8	40	14	39	10	7	0	53	3	57	0	46
12	9	3	14	38	9	50	0	37	3	59	0	34
13	9	26	14	36	9	33	0	21	4	0	0	21
14	9	47	14	33	9	16	0	6	4	0	0	9
15	10	8	14	30	8	59	0 *	9	4	0	0 *	4
							Sun fast of clock.				Sun slow of clock.	
16	10	28	14	26	8	41	0	24	3	59	0	17
17	10	48	14	21	8	23	0	38	3	58	0	30
18	11	7	14	16	8	6	0	52	3	55	0	43
19	11	26	14	10	7	48	1	5	3	52	0	56
20	11	43	14	3	7	30	1	18	3	49	1	9
21	11	59	13	55	7	11	1	31	3	46	1	22
22	12	15	13	47	6	53	1	43	3	42	1	35
23	12	30	13	38	6	34	1	55	3	37	1	47
24	12	44	13	29	5	16	2	6	3	32	2	0
25	12	58	13	69	1	57	2	17	3	27	2	13
26	13	10	13	8	5	38	2	27	3	21	2	25
27	13	21	12	56	5	19	2	37	3	14	2	37
28	13	32	12	44	5	1	2	47	3	7	2	49
29	13	42			4	42	2	56	2	59	3	1
30	13	52			4	23	3		2	51	3	13
31	14	0			4	5			2	43		

Equation of time. The sun faster or slower than the clock. Second after bissextile.											
July.		Aug.		Sept.		Oct.		Nov.		Dec.	
Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock.		Sun fast of clock. * Sun sl. cl.	
M.	S.	M.	S.	M.	S.	M.	S.	M.	S.	M	S.
3	24	5	52	0	24	10	32	16	14	15	23
3	35	5	48	0	43	10	50	16	14	9	59
3	46	5	43	1	2	11	9	16	14	9	35
3	57	5	38	1	21	11	27	16	12	9	11
4	7	5	32	1	41	11	44	16	9	8	45
4	18	5	26	2	0	12	1	16	6	8	19
4	28	5	19	2	20	12	17	16	2	7	53
4	37	5	11	2	41	12	33	15	58	7	26
4	46	5	3	3	1	12	49	15	52	6	59
4	55	4	54	3	21	13	5	15	46	6	31
5	3	4	45	3	42	13	20	15	38	6	3
5	11	4	35	4	3	13	34	15	30	5	35
5	18	4	25	4	23	13	48	15	21	5	6
5	25	4	14	4	44	14	2	15	11	4	37
5	31	4	2	5	5	14	15	15	1	4	8
5	37	3	50	5	26	14	27	14	49	3	39
5	42	3	38	5	47	14	38	14	37	3	9
5	47	3	25	6	8	14	49	14	24	2	40
5	51	3	12	6	29	15	0	14	10	2	10
5	55	2	58	6	50	15	10	13	55	1	40
5	58	2	43	7	11	15	20	13	40	1	10
6	0	2	28	7	32	15	28	13	23	0	40
6	2	2	13	7	53	15	36	13	6	0	10
6	3	1	57	8	13	15	43	12	48	0 *	20
6	4	1	40	8	34	15	50	12	30	0	50
6	4	1	23	8	54	15	55	12		1	19
6	3	1	6	9	14	16	0	11	51	1	49
6	2	0	49	9	34	16	5	11	30	2	18
6	1	0	31	9	53	16	9	11	8	2	48
5	58	0	13	10	13	16	11	10	46	3	17
5	55	0 *	5			16	12			3	46

Equation of time. The sun faster or slower than the clock.

Third after bissextile.

Days.	Jan. M.	Jan. S.	Feb. M.	Feb. S.	March. M.	March. S.	April. M.	April. S.	May. M.	May. S.	June. M.	June. S.
	Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun slow of clock.		Sun fast of clock.		Sun fast of clock.	
1	4	14	14	5	12	35	3	51	3	9	2	36
2	4	42	14	12	12	22	3	32	3	16	2	27
3	5	10	14	18	12	9	3	14	3	23	2	17
4	5	38	14	24	11	56	2	53	3	29	2	7
5	6	5	14	29	11	42	2	39	3	35	1	57
6	6	31	14	33	11	28	2	21	3	40	1	46
7	6	57	14	35	11	14	2	4	3	44	1	35
8	7	22	14	37	10	59	1	47	3	48	1	24
9	7	47	14	39	10	43	1	30	3	52	1	12
10	8	11	14	40	10	27	1	14	3	54	1	0
11	8	35	14	40	10	11	0	58	3	56	0	48
12	8	58	14	39	9	54	0	42	3	58	0	36
13	9	21	14	37	9	37	0	26	3	59	0	24
14	9	42	14	34	9	20	0	10	4	0	0	12
15	10	3	14	30	9	3	0	* 5	4	0	0	* 1
							Sun fast of clock.				Sun slow of clock.	
16	10	24	14	26	8	45	0	20	3	59	0	13
17	10	43	14	22	8	28	0	35	3	58	0	26
18	11	2	14	16	8	10	0	49	3	56	0	39
19	11	20	14	10	7	52	1	3	3	54	0	52
20	11	38	14	3	7	33	1	16	3	51	1	5
21	11	54	13	55	7	15	1	29	3	48	1	17
22	12	10	13	47	6	56	1	41	3	44	1	30
23	12	25	13	39	6	38	1	53	3	39	1	43
24	12	39	13	30	6	19	2	4	3	34	1	56
25	12	53	13	20	6	0	2	15	3	29	2	9
26	13	6	13	10	5	42	2	25	3	23	2	21
27	13	17	12	59	5	23	2	35	3	16	2	34
28	13	28	12	47	5	4	2	45	3	9	2	46
29	13	39			4	46	2	54	3	1	2	59
30	13	49			4	27	3	2	2	53	3	11
31	13	58			4	9			2	45		

Equation of time. The sun faster or slower than the clock.

Third after bissextile.

July.			Aug.			Sept.			Oct.			Nov.			Dec.		
M.		S.	M.		S.	M.		S.	M.		S.	M.		S.	M.		S.
3	Sun slow	22	5	Sun slow	53	0	Sun fast	9	10	Sun fast	27	16	Sun fast	13	10	Sun fast	28
3		33	5		49	0		38	10		46	16		14	10		5
3		44	5		45	0		57	11		4	16		14	9		41
3		55	5		40	1		16	11		22	16		13	9		17
4		6	5		34	1		36	11		40	16		10	8		51
4	of clock.	16	5	of clock	28	1	of clock.	55	11	of clock.	57	16	of clock.	7	8	of clock.	25
4		26	5		21	2		15	12		14	16		4	7		59
4		36	5		13	2		36	12		30	16		0	7		33
4		45	5		5	2		56	12		46	15		54	7		6
4		54	4		56	3		17	13		2	15		48	6		39
5		2	4		47	3		38	13		17	15		41	6		11
5		9	4		38	3		58	13		32	15		33	5		43
5		16	4		27	4		19	13		46	15		25	5		14
5		23	4		16	4		40	14		0	15		15	4		46
5		29	4		4	5		1	14		13	15		5	4		17
5		35	3		52	5		23	14		26	14		53	3		48
5		40	3		40	5		44	14		37	14		41	3		18
5		45	3		27	6		5	14		48	14		28	2		48
5		49	3		14	6		26	14		59	14		15	2		18
5		53	3		0	6		47	15		9	4		0	1		48
5		56	2		45	7		8	15		19	13		45	1		18
5		58	2		31	7		28	15		27	13		28	0		48
6		0	2		16	7		49	15		35	13		11	0		18
6		2	2		0	8		9	15		42	12		53	0	*	12
6		3	1		44	8		29	15		49	12		35	0		42
6		3	1		27	8		50	15		54	12		16	1	Sun sl. cl.	12
6		3	1		10	9		10	16		0	11		56	1		42
6		2	0		53	9		29	16		4	11		35	2		12
6		1	0		35	9		49	16		8	11		13	2		41
5		59	0		18	10		8	16		10	10		51	3		11
5		56	0	*	0				16		12				3		40

TABLE XIX.—*Proportional Logarithms.*

	0	1	2	3	4	5	6	7
0	00000	17782	14771	13010	11761	10792	10000	9331
1	35563	17710	14735	12986	11743	10777	9988	9320
2	32553	17639	14699	12962	11725	10763	9976	9310
3	30792	17570	14664	12939	11707	10749	9964	9300
4	29542	17501	14629	12915	11689	10734	9952	9289
5	28573	17434	14594	12891	11671	10720	9940	9279
6	27782	17368	14559	12868	11654	10706	9928	9269
7	27112	17302	14525	12845	11636	10692	9916	9259
8	26532	17238	14491	12821	11619	10678	9905	9249
9	26021	17175	14457	12798	11601	10663	9893	9238
10	25563	17112	14424	12776	11584	10649	9881	9228
11	25149	17050	14390	12753	11566	10635	9869	9218
12	24771	16990	14357	12730	11549	10622	9858	9208
13	24424	16930	14325	12707	11532	10608	9846	9198
14	24102	16871	14292	12685	11515	10594	9834	9188
15	23802	16812	14260	12663	11498	10580	9823	9178
16	23522	16755	14228	12640	11481	10566	9811	9168
17	23259	16698	14196	12618	11464	10552	9800	9158
18	23010	16642	14164	12596	11447	10539	9788	9148
19	22775	16587	14133	12575	11430	10525	9777	9138
20	22553	16532	14102	12553	11413	10512	9765	9129
21	22341	16478	14071	12531	11397	10498	9754	9119
22	22139	16425	14040	12510	11380	10484	9742	9109
23	21946	16372	14010	12488	11363	10471	9731	9099
24	21761	16320	13979	12467	11347	10458	9720	9089
25	21584	16269	13949	12446	11331	10444	9708	9079
26	21413	16218	13920	12424	11314	10431	9697	9070
27	21249	16168	13890	12403	11298	10418	9686	9060
28	21091	16118	13860	12382	11282	10404	9675	9050
29	20939	16069	13831	12362	11266	10391	9664	9041
30	20792	16021	13802	12341	11249	10378	9652	9031

Table of Proportional Logarithms.

	0	1	2	3	4	5	6	7
30	20792	16021	13802	12341	11249	10378	9652	9031
31	20649	15973	13773	12320	11233	10365	9641	9021
32	20512	15925	13745	12300	11217	10352	9630	9012
33	20378	15878	13716	12279	11201	10339	9619	9002
34	20248	15832	13688	12259	11186	10326	9608	8992
35	20122	15786	13660	12239	11170	10313	9597	8983
36	20000	15740	13632	12218	11154	10300	9586	8973
37	19881	15695	13604	12198	11138	10287	9575	8964
38	19765	15651	13576	12178	11123	10274	9564	8954
39	19652	15607	13549	12159	11107	10261	9553	8945
40	19542	15563	13522	12139	11091	10248	9542	8935
41	19435	15520	13495	12119	11076	10235	9532	8926
42	19331	15477	13468	12099	11061	10223	9521	8917
43	19228	15435	13441	12080	11045	10210	9510	8907
44	19128	15393	13415	12061	11030	10197	9499	8898
45	19031	15351	13388	12041	11015	10185	9488	8889
46	18935	15310	13362	12022	10999	10172	9478	8879
47	18842	15269	13336	12003	10984	10160	9467	8870
48	18751	15229	13310	11984	10969	10147	9456	8861
49	18661	15189	13284	11965	10954	10135	9446	8851
50	18573	15149	13259	11946	10939	10122	9435	8842
51	18487	15110	13233	11927	10924	10110	9425	8833
52	18403	15071	13208	11908	10909	10098	9414	8824
53	18320	15032	13183	11889	10894	10085	9404	8814
54	18239	14994	13158	11871	10880	10073	9393	8805
55	18159	14956	13133	11852	10865	10061	9383	8796
56	18081	14918	13108	11834	10850	10049	9372	8787
57	18004	14881	13083	11816	10835	10036	9362	8778
58	17929	14844	13059	11797	10821	10024	9351	8769
59	17855	14808	13034	11779	10806	10012	9341	8760
60	17782	14771	13010	11761	10792	10000	9331	8751

Table of Proportional Logarithms.

	8	9	10	11	12	13	14	15	16
0	8751	8239	7782	7368	6990	6642	6320	6021	5740
1	8742	8231	7774	7361	6984	6637	6315	6016	5736
2	8733	8223	7767	7354	6978	6631	6310	6011	5731
3	8724	8215	7760	7348	6972	6625	6305	6006	5727
4	8715	8207	7753	7341	6966	6620	6300	6001	5722
5	8706	8199	7745	7335	6960	6614	6294	5997	5718
6	8697	8191	7738	7328	6954	6609	6289	5992	5713
7	8688	8183	7731	7322	6948	6603	6284	5987	5709
8	8679	8175	7724	7315	6942	6598	6279	5982	5704
9	8670	8167	7717	7309	6936	6592	6274	5977	5700
10	8661	8159	7710	7302	6930	6587	6269	5973	5695
11	8652	8152	7703	7296	6924	6581	6264	5968	5691
12	8643	8144	7696	7289	6918	6576	6259	5963	5686
13	8635	8136	7688	7283	6912	6570	6254	5958	5682
14	8626	8128	7681	7276	6906	6565	6248	5954	5677
15	8617	8120	7674	7270	6900	6559	6243	5949	5673
16	8608	8112	7667	7264	6894	6554	6238	5944	5669
17	8599	8104	7660	7257	6888	6548	6233	5939	5664
18	8591	8097	7653	7251	6882	6543	6228	5935	5660
19	8582	8089	7646	7244	6877	6538	6223	5930	5655
20	8573	8081	7639	7238	6871	6532	6218	5925	5651
21	8565	8073	7632	7232	6865	6527	6213	5920	5640
22	8556	8066	7625	7225	6859	6521	6208	5916	5642
23	8547	8058	7618	7219	6853	6516	6203	5911	5638
24	8539	8050	7611	7212	6847	6510	6198	5906	5633
25	8530	8043	7604	7206	6841	6505	6193	5902	5629
26	8522	8035	7597	7200	6836	6500	6188	5897	5624
27	8513	8027	7590	7193	6830	6494	6183	5892	5620
28	8504	8020	7583	7187	6824	6489	6178	5888	5615
29	8496	8012	7577	7181	6818	6484	6173	5883	5611
30	8487	8004	7570	7175	6812	6478	6168	5878	5607

Table of Proportional Logarithms.

	8	9	10	11	12	13	14	15	16
30	8487	8004	7570	7175	6812	6478	6168	5878	5607
31	8479	7997	7563	7168	6807	6473	6163	5874	5602
32	8470	7989	7556	7162	6801	6467	6158	5869	5598
33	8462	7982	7549	7156	6795	6462	6153	5864	5594
34	8453	7974	7542	7149	6789	6457	6148	5860	5589
35	8445	7966	7535	7143	6784	6451	6143	5855	5585
36	8437	7959	7528	7137	6778	6446	6138	5850	5580
37	8428	7951	7522	7131	6772	6441	6133	5846	5576
38	8420	7944	7515	7124	6766	6435	6128	5841	5572
39	8411	7936	7508	7118	6761	6430	6123	5836	5567
40	8403	7929	7501	7112	6755	6425	6118	5832	5563
41	8395	7921	7494	7106	6749	6420	6113	5827	5559
42	8386	7914	7488	7100	6744	6414	6108	5823	5554
43	8378	7906	7481	7093	6738	6409	6103	5818	5550
44	8370	7899	7474	7087	6732	6404	6099	5813	5546
45	8361	7891	7467	7081	6726	6398	6094	5809	5541
46	8353	7884	7461	7075	6721	6393	6089	5804	5537
47	8345	7877	7454	7069	6715	6388	6084	5800	5533
48	8337	7869	7447	7063	6709	6383	6079	5795	5528
49	8328	7862	7441	7057	6704	6377	6074	5790	5524
50	8320	7855	7434	7050	6698	6372	6069	5786	5520
51	8312	7847	7427	7044	6693	6367	6064	5781	5516
52	8304	7840	7421	7038	6687	6362	6059	5777	5511
53	8296	7833	7414	7032	6681	6357	6055	5772	5507
54	8288	7825	7407	7026	6676	6351	6050	5768	5503
55	8280	7818	7401	7020	6670	6346	6045	5763	5498
56	8271	7811	7394	7014	6664	6341	6040	5758	5494
57	8263	7803	7387	7008	6659	6336	6035	5754	5490
58	8255	7796	7381	7002	6653	6331	6030	5749	5486
59	8247	7789	7374	6996	6648	6325	6025	5745	5481
60	8239	7782	7368	6990	6642	6320	6021	5740	5477

Table of Proportional Logarithms.

	17	18	19	20	21	22	23	24	25
0	5477	5229	4994	4771	4559	4357	4164	3979	3802
1	5473	5225	4990	4768	4556	4354	4161	3976	3799
2	5469	5221	4986	4764	4552	4351	4158	3973	3796
3	5464	5217	4983	4760	4549	4347	4155	3970	3793
4	5460	5213	4979	4757	4546	4344	4152	3967	3791
5	5456	5209	4975	4753	4542	4341	4149	3964	3788
6	5452	5205	4971	4750	4539	4338	4145	3961	3785
7	5447	5201	4967	4746	4535	4334	4142	3958	3782
8	5443	5197	4964	4742	4532	4331	4139	3955	3779
9	5439	5193	4960	4739	4528	4328	4136	3952	3776
10	5435	5189	4956	4735	4525	4325	4133	3949	3773
11	5430	5185	4952	4732	4522	4321	4130	3946	3770
12	5426	5181	4949	4728	4518	4318	4127	3943	3768
13	5422	5177	4945	4724	4515	4315	4124	3940	3765
14	5418	5173	4941	4721	4511	4311	4120	3937	3762
15	5414	5169	4937	4717	4508	4308	4117	3934	3759
16	5409	5165	4933	4714	4505	4305	4114	3931	3756
17	5405	5161	4930	4710	4501	4302	4111	3928	3753
18	5401	5157	4926	4707	4498	4298	4108	3925	3750
19	5397	5153	4922	4703	4494	4295	4105	3922	3747
20	5393	5149	4918	4699	4491	4292	4102	3920	3745
21	5389	5145	4915	4696	4488	4289	4099	3917	3742
22	5384	5141	4911	4692	4484	4286	4096	3914	3739
23	5380	5137	4907	4689	4481	4282	4092	3911	3736
24	5376	5133	4904	4685	4477	4279	4089	3908	3733
25	5372	5129	4900	4682	4474	4276	4086	3905	3730
26	5368	5125	4896	4678	4471	4273	4083	3902	3727
27	5364	5122	4892	4674	4467	4269	4080	3899	3725
28	5359	5118	4889	4671	4464	4266	4077	3896	3722
29	5355	5114	4885	4668	4461	4263	4074	3893	3719
30	5351	5110	4881	4664	4457	4260	4071	3890	3716

Table of Proportional Logarithms.

	17	18	19	20	21	22	23	24	25
30	5351	5110	4881	4664	4457	4260	4071	3890	3716
31	5347	5106	4877	4660	4454	4256	4068	3887	3713
32	5343	5102	4874	4657	4450	4253	4065	3884	3710
33	5339	5098	4870	4653	4447	4250	4062	3881	3708
34	5335	5094	4866	4650	4444	4247	4059	3878	3705
35	5331	5090	4863	4646	4440	4244	4055	3875	3702
36	5326	5086	4859	4643	4437	4240	4052	3872	3699
37	5322	5083	4855	4639	4434	4237	4049	3869	3696
38	5318	5079	4852	4636	4430	4234	4046	3866	3693
39	5314	5075	4848	4632	4427	4231	4043	3863	3691
40	5310	5071	4844	4629	4424	4228	4040	3860	3688
41	5306	5067	4841	4625	4420	4224	4037	3857	3685
42	5302	5063	4837	4622	4417	4221	4034	3855	3682
43	5298	5059	4833	4618	4414	4218	4031	3852	3679
44	5294	5055	4830	4615	4410	4215	4028	3849	3677
45	5290	5052	4826	4611	4407	4212	4025	3846	3674
46	5285	5048	4822	4608	4404	4209	4022	3843	3671
47	5281	5044	4819	4604	4400	4205	4019	3840	3668
48	5277	5040	4815	4601	4397	4202	4016	3837	3665
49	5273	5036	4811	4597	4394	4199	4013	3834	3663
50	5269	5032	4808	4594	4390	4196	4010	3831	3660
51	5265	5028	4804	4590	4387	4193	4007	3828	3657
52	5261	5025	4800	4587	4384	4190	4004	3825	3654
53	5257	5021	4797	4584	4380	4186	4001	3822	3651
54	5253	5017	4793	4580	4377	4183	3998	3820	3649
55	5249	5013	4789	4577	4374	4180	3995	3817	3646
56	5245	5009	4786	4573	4370	4177	3992	3814	3643
57	5241	5005	4782	4570	4367	4174	3988	3811	3640
58	5237	5002	4778	4566	4364	4171	3985	3808	3637
59	5233	4998	4775	4563	4361	4167	3982	3805	3635
60	5229	4994	4771	4559	4357	4164	3979	3802	3632

Table of Proportional Logarithms.

	26	27	28	29	30	31	32	33	34
0	3632	3468	3310	3158	3010	2868	2730	2596	2467
1	3629	3465	3307	3155	3008	2866	2728	2594	2465
2	3626	3463	3305	3153	3006	2863	2726	2592	2462
3	3623	3460	3302	3150	3003	2861	2723	2590	2460
4	3621	3457	3300	3148	3001	2859	2721	2588	2458
5	3618	3455	3297	3145	2998	2856	2719	2585	2456
6	3615	3452	3294	3143	2996	2854	2716	2583	2454
7	3612	3449	3292	3140	2993	2852	2714	2581	2452
8	3610	3447	3289	3138	2991	2849	2712	2579	2450
9	3607	3444	3287	3135	2989	2847	2710	2577	2448
10	3604	3441	3284	3133	2986	2845	2707	2575	2446
11	3601	3439	3282	3130	2984	2842	2705	2572	2443
12	3599	3436	3279	3128	2981	2840	2703	2570	2441
13	3596	3433	3276	3125	2979	2838	2701	2568	2439
14	3593	3431	3274	3123	2977	2835	2698	2566	2437
15	3590	3428	3271	3120	2974	2833	2696	2564	2435
16	3587	3425	3269	3118	2972	2831	2694	2561	2433
17	3585	3423	3266	3115	2970	2828	2692	2559	2431
18	3582	3420	3264	3113	2967	2826	2690	2557	2429
19	3579	3417	3261	3110	2965	2824	2687	2555	2426
20	3576	3415	3259	3108	2962	2821	2685	2553	2424
21	3574	3412	3256	3105	2960	2819	2683	2551	2422
22	3571	3409	3253	3103	2958	2817	2681	2548	2420
23	3568	3407	3251	3101	2955	2815	2678	2546	2418
24	3565	3404	3248	3098	2953	2812	2676	2544	2416
25	3563	3401	3246	3096	2950	2810	2674	2542	2414
26	3560	3399	3243	3093	2948	2808	2672	2540	2412
27	3557	3396	3241	3091	2946	2805	2669	2538	2410
28	3555	3393	3238	3088	2943	2803	2667	2535	2408
29	3552	3391	3236	3086	2941	2801	2665	2533	2405
30	3549	3388	3233	3083	2939	2798	2663	2531	2403

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	26	27	28	29	30	31	32	33	34
30	3549	3388	3233	3083	2939	2798	2663	2531	2403
31	3546	3386	3231	3081	2936	2796	2660	2529	2401
32	3544	3383	3228	3078	2934	2794	2658	2527	2399
33	3541	3380	3225	3076	2931	2792	2656	2525	2397
34	3538	3378	3223	3074	2929	2789	2654	2522	2395
35	3535	3375	3220	3071	2927	2787	2652	2520	2393
36	3533	3372	3218	3069	2924	2785	2649	2518	2391
37	3530	3370	3215	3066	2922	2782	2647	2516	2389
38	3527	3367	3213	3064	2920	2780	2645	2514	2387
39	3525	3365	3210	3061	2917	2778	2643	2512	2385
40	3522	3362	3208	3059	2915	2776	2640	2510	2382
41	3519	3359	3205	3056	2913	2773	2638	2507	2380
42	3516	3357	3203	3054	2910	2771	2636	2505	2376
43	3514	3354	3200	3052	2908	2769	2634	2503	2378
44	3511	3352	3198	3049	2905	2766	2632	2501	2374
45	3508	3349	3195	3047	2903	2764	2629	2499	2372
46	3506	3346	3193	3044	2901	2762	2627	2497	2370
47	3503	3344	3190	3042	2898	2760	2625	2495	2368
48	3500	3341	3188	3039	2896	2757	2623	2492	2366
49	3497	3338	3185	3037	2894	2755	2621	2490	2364
50	3495	3336	3183	3035	2891	2753	2618	2488	2362
51	3492	3333	3180	3032	2889	2750	2616	2486	2360
52	3489	3331	3178	3030	2887	2748	2614	2484	2357
53	3487	3328	3175	3027	2884	2746	2612	2482	2355
54	3484	3325	3173	3025	2882	2744	2610	2480	2353
55	3481	3323	3170	3022	2880	2741	2607	2477	2351
56	3479	3320	3168	3020	2877	2739	2605	2475	2349
57	3476	3318	3165	3018	2875	2737	2603	2473	2347
58	3473	3315	3163	3015	2873	2735	2601	2471	2345
59	3471	3313	3160	3013	2870	2732	2599	2469	2343
60	3468	3310	3158	3010	2868	2730	2596	2467	2341

Table of Proportional Logarithms.

	35	36	37	38	39	40	41	42	43
0	2341	2219	2100	1984	1871	1761	1654	1549	1447
1	2339	2217	2098	1982	1869	1759	1652	1547	1445
2	2337	2214	2096	1980	1867	1757	1650	1546	1443
3	2335	2212	2094	1978	1865	1756	1648	1544	1442
4	2333	2210	2092	1976	1863	1754	1647	1542	1440
5	2331	2208	2090	1974	1862	1752	1645	1540	1438
6	2328	2206	20[illegible]8	1972	1860	1750	1643	1539	1437
7	2326	2204	2086	1970	1858	1748	1641	1537	1435
8	2324	2202	2084	1968	1856	1746	1640	1535	1433
9	2322	2200	2082	1967	1854	1745	1638	1534	1432
10	2320	2198	2080	1965	1852	1743	1636	1532	1430
11	2318	2196	2078	1963	1851	1741	1634	1530	1428
12	2316	2194	2076	1961	1849	1739	1633	1528	1427
13	2314	2192	2074	1959	1847	1737	1631	1527	1425
14	2312	2190	2072	1957	1845	1736	1629	1525	1423
15	2310	2188	2070	1955	1843	1734	1627	1523	1422
16	2308	2186	2068	1953	1841	1732	1626	[illegible]522	1420
17	2306	2184	2066	1951	1839	1730	1624	1520	1418
18	2304	2182	2064	1950	1838	1728	1622	1518	1417
19	2302	2180	2063	1948	1836	1727	1620	1516	1415
20	2300	2178	2061	1946	1834	1725	1619	1515	1413
21	2298	2176	2059	1944	1832	1723	1617	[illegible]513	1412
22	2296	2175	2057	1942	1830	1721	1615	1511	1410
23	2294	2173	2055	1940	1828	1720	1613	1510	1408
24	2292	2171	2053	1938	1827	1718	1612	1508	1407
25	2289	2169	2051	1936	1825	1716	1610	1506	1405
26	2287	2167	2049	1934	1823	1714	1608	1504	1403
27	2285	2165	2047	1933	1821	1712	1606	1503	1402
28	2283	2163	2045	1931	1819	1711	1605	1501	1400
29	2281	2161	2043	1929	1817	1709	1603	1499	1398
30	2279	2159	2041	1927	1816	1707	1601	1498	1397

Table of Proportional Logarithms.

	35	36	37	38	39	40	41	42	43
30	2279	2159	2041	1927	1816	1707	1601	1498	1397
31	2277	2157	2039	1925	1814	1705	1599	1496	1395
32	2275	2155	2037	1923	1812	1703	1598	1494	1393
33	2273	2153	2035	1921	1810	1702	1596	1493	1392
34	2271	2151	2034	1919	1808	1700	1594	1491	1390
35	2269	2149	2032	1918	1806	1698	1592	1489	1388
36	2267	2147	2030	1916	1805	1696	1591	1487	1387
37	2265	2145	2028	1914	1803	1694	1589	1486	1385
38	2263	2143	2026	1912	1801	1693	1587	1484	1383
39	2261	2141	2024	1910	1799	1691	1585	1482	1382
40	2259	2139	2022	1908	1797	1689	1584	1481	1380
41	2257	2137	2020	1906	1795	1687	1582	1479	1378
42	2255	2135	2018	1904	1794	1686	1580	1477	1377
43	2253	2133	2016	1903	1792	1684	1578	1476	1375
44	2251	2131	2014	1901	1790	1682	1577	1474	1373
45	2249	2129	2012	1899	1788	1680	1575	1472	1372
46	2247	2127	2010	1897	1786	1678	1573	1470	1370
47	2245	2125	2009	1895	1785	1677	1572	1469	1368
48	2243	2123	2007	1893	1783	1675	1570	1467	1367
49	2241	2121	2005	1891	1781	1673	1568	1465	1365
50	2239	2119	2003	1889	1779	1671	1566	1464	1363
51	2237	2117	2001	1888	1777	1670	1565	1462	1362
52	2235	2115	1999	1886	1775	1668	1563	1460	1360
53	2233	2113	1997	1884	1774	1666	1561	1459	1359
54	2231	2111	1995	1882	1772	1664	1559	1457	1357
55	2229	2109	1993	1880	1770	1663	1558	1455	1355
56	2227	2107	1991	1878	1768	1661	1556	1454	1354
57	2225	2105	1989	1876	1766	1659	1554	1452	1352
58	2223	2103	1988	1875	1765	1657	1552	1450	1350
59	2221	2101	1986	1873	1763	1655	1551	1449	1349
60	2218	2099	1984	1871	1761	1654	1549	1447	1347

Table of Proportional Logarithms.

	44	45	46	47	48	49	50	51	52
0	1347	1249	1154	1061	969	880	792	706	622
1	1345	1248	1152	1059	968	878	790	704	620
2	1344	1246	1151	1057	966	877	789	703	619
3	1342	1245	1149	1056	965	875	787	702	617
4	1340	1243	1148	1054	963	874	786	700	616
5	1339	1241	1146	1053	962	872	785	699	615
6	1337	1240	1145	1051	960	871	783	697	613
7	1336	1238	1143	1050	959	869	782	696	612
8	1334	1237	1141	1048	957	868	780	694	610
9	1332	1235	1140	1047	956	866	779	693	609
10	1331	1233	1138	1045	954	865	777	692	608
11	1329	1232	1137	1044	953	863	776	690	606
12	1327	1230	1135	1042	951	862	775	689	605
13	1326	1229	1134	1041	950	860	773	687	603
14	1324	1227	1132	1039	948	859	772	686	602
15	1322	1225	1130	1038	947	857	770	685	601
16	1321	1224	1129	1036	945	856	769	683	599
17	1319	1222	1127	1034	944	855	767	682	598
18	1318	1221	1126	1033	942	853	766	680	597
19	1316	1219	1124	1031	941	852	764	679	595
20	1314	1217	1123	1030	939	850	763	678	594
21	1313	1216	1121	1028	938	849	762	676	592
22	1311	1214	1119	1027	936	847	760	675	591
23	1309	1213	1118	1025	935	846	759	673	590
24	1308	1211	1116	1024	933	844	757	672	588
25	1306	1209	1115	1022	932	843	756	670	587
26	1304	1208	1113	1021	930	841	754	669	585
27	1303	1206	1112	1019	929	840	753	668	584
28	1301	1205	1110	1018	927	838	751	666	583
29	1300	1203	1109	1016	926	837	750	665	581
30	1298	1201	1107	1015	924	835	749	663	580

Table of Proportional Logarithms.

	44	45	46	47	48	49	50	51	52
30	1298	1201	1107	1015	924	835	749	663	580
31	1296	1200	1105	1013	923	834	747	662	579
32	1295	1198	1104	1012	921	833	746	661	577
33	1293	1197	1102	1010	920	831	744	659	576
34	1291	1195	1101	1009	918	830	743	658	574
35	1290	1193	1099	1007	917	828	741	656	573
36	1288	1192	1098	1005	915	827	740	655	572
37	1287	1190	1096	1004	914	825	739	654	570
38	1285	1189	1095	1002	912	824	737	652	569
39	1283	1187	1093	1001	911	822	736	651	568
40	1282	1186	1091	999	909	821	734	649	566
41	1280	1184	1090	998	908	819	733	648	565
42	1278	1182	1088	996	906	818	731	647	563
43	1277	1181	1087	995	905	817	730	645	562
44	1275	1179	1085	993	903	815	729	644	561
45	1274	1178	1084	992	902	814	727	642	559
46	1272	1176	1082	990	900	812	726	641	558
47	1270	1174	1081	989	899	811	724	640	557
48	1269	1173	1079	987	897	809	723	638	555
49	1267	1171	1078	986	896	808	721	637	554
50	1266	1170	1076	984	894	806	720	635	552
51	1264	1168	1074	983	893	805	719	634	551
52	1262	1167	1073	981	891	803	717	633	550
53	1261	1165	1071	980	890	802	716	631	548
54	1259	1163	1070	978	888	801	714	630	547
55	1257	1162	1068	977	887	799	713	628	546
56	1256	1160	1067	975	885	798	712	627	544
57	1254	1159	1065	974	884	796	710	626	543
58	1253	1157	1064	972	883	795	709	624	542
59	1251	1156	1062	971	881	793	707	623	540
60	1249	1154	1061	969	880	792	706	621	539

Table of Proportional Logarithms.

	53	54	55	56	57	58	59		53	54	55	56	57	58	59
0	539	458	378	300	223	147	73	30	498	418	339	261	185	110	36
1	537	456	377	298	222	146	72	31	497	416	337	260	184	109	35
2	536	455	375	297	220	145	71	32	495	415	336	258	182	108	34
3	535	454	374	296	219	144	69	33	494	414	335	257	181	106	33
4	533	452	373	294	218	142	68	34	493	412	333	256	180	105	32
5	532	451	371	293	216	141	67	35	491	411	332	255	179	104	30
6	531	450	370	292	215	140	66	36	490	410	331	253	177	103	29
7	529	448	369	291	214	139	64	37	489	408	329	252	176	101	28
8	528	447	367	289	213	137	63	38	487	407	328	251	175	100	27
9	527	446	366	288	211	136	62	39	486	406	327	250	174	99	25
10	525	444	365	287	210	135	61	40	484	404	326	248	172	98	24
11	524	443	363	285	209	134	60	41	483	403	324	247	171	96	23
12	522	442	362	284	208	132	58	42	482	402	323	246	170	95	22
13	521	440	361	283	206	131	57	43	480	400	322	244	169	94	21
14	520	439	360	282	205	130	56	44	479	399	320	243	167	93	19
15	518	438	358	280	204	129	55	45	478	398	319	242	166	91	18
16	517	436	357	279	203	127	53	46	476	396	318	241	165	90	17
17	516	435	356	278	201	126	52	47	475	395	316	239	164	89	16
18	514	434	354	276	200	125	51	48	474	394	315	238	162	88	15
19	513	432	353	275	199	124	50	49	472	392	314	237	161	87	13
20	512	431	352	274	197	122	49	50	471	391	313	236	160	85	12
21	510	430	350	273	196	121	47	51	470	390	311	234	159	84	11
22	509	428	349	271	195	120	46	52	468	388	310	233	157	83	10
23	507	427	348	270	194	119	45	53	467	387	309	232	156	82	8
24	506	426	346	269	192	117	44	54	466	386	307	230	155	80	7
25	505	424	345	267	191	116	42	55	464	384	306	229	154	79	6
26	503	423	344	266	190	115	41	56	463	383	305	228	152	78	5
27	502	422	343	265	189	114	40	57	462	382	304	227	151	77	4
28	501	420	341	264	187	112	39	58	460	381	302	225	150	75	2
29	499	419	340	262	186	111	38	59	459	379	301	224	149	74	1
30	498	418	339	261	185	110	36	60	458	378	300	223	147	73	0

INDEX.

[A.]

[B.]

[C.]

[F.]

[G.]

[H.]